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Importance of correction of surface temperature maps in urban environment

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Abstract

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. In this article, we will quantify the errors on surface temperature measurements due to these influencing parameters values. We will also 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.

1. Introduction

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. 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. This leads to:

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

where T_0 and T_{air} are the surface and air temperature respectively, ε is the apparent emissivity and τ is the atmosphere transmittance. Most of materials of building facades can be often assimilated to grey, highly emissive and diffuse surfaces. In that situation, a “standard” value of the emissivity is generally considered and the contribution of the surrounding environment is simplified to an equivalent black-body emitting at a mean-radiant temperature T_{env} [1,2]. Nevertheless, low emissivity materials and specular surfaces on buildings façades or roofs (e.g. metallic claddings, selective paints, etc.) are now commonly used in order to lower heat losses, leading to highly heterogeneous environments and possible parasitic multiple reflexions, which must be considered for surface temperatures estimation. Moreover, erosion, soiling and ageing of materials lead to temporal evolution of surface radiative properties. Thus, new solutions must be developed to obtain accurate surface temperature measurement using IR thermography in such context.

2. Quantification of errors due to influencing parameters

The surface temperature T_0 is the objective parameter to further obtain information for instance on heat losses on a building façade. The knowledge of influencing parameters T_{env}, ε, τ and T_{air} is thus required. In figure 1, several charts present the difference between apparent and true surface temperatures as a function of possible values of influencing parameters. Errors due to the atmosphere contribution remain low for classical measurement situations: τ parameter is greater than 0.95 for measurement distances up to 50 meters in normal relative humidity conditions. For high emissivity surfaces (e.g. concrete, stone, paintings…), the temperature correction is generally small. It was shown in previous studies that these contributions could be evaluated on site and that corrected temperature close to expected ones could be obtained during a measurement campaign (example in paper [3]). For low emissivity surfaces, the contribution of surrounding radiation becomes predominant and an accurate characterization of the environment radiation becomes necessary to minimize the measurement bias on corrected temperature.

3. Illustration of the importance of environment radiation modelling for outdoor in-situ situations

We consider here the case of two buildings built in 2017 in Paris. Left building has a specular low emissivity surface (assumed around 0.2) whereas the emissivity of the right building surface is high (around 0.9). A thermal image of these buildings is presented in figure 2. These buildings were built at the same time, 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 surface temperature for both buildings external surfaces. Several corrected temperatures were computed (see table 1 for results) by considering the assumed (“reference”) emissivity value for each surface and different values of T_{env} (-1.1°C: sky temperature; +2°C: average value of surroundings temperature (buildings, sky, pavements); +5°C: average value of surrounding building surfaces only) on one hand, and a T_{env} value of +2°C (*i.e.* computed classically by averaging the contribution of all surrounding environment [1]) and a variation of ±0.1 of surface emissivity around reference value for each building on the other hand.

As expected, there is a small influence of T_{env} value for the highest emissivity surface. On the contrary, the choice of T_{env} value is of great importance for the low emissive surface. To obtain a corrected surface temperature equal to the one of the right building, we have to use one of the following couple of values: 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. The new problem posed is how to reach such accuracy on T_{env} value regarding metrological uncertainties. This illustrates the great importance of the modelling of environment radiation for low emissivity and/or specular surfaces.

Table 1. *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

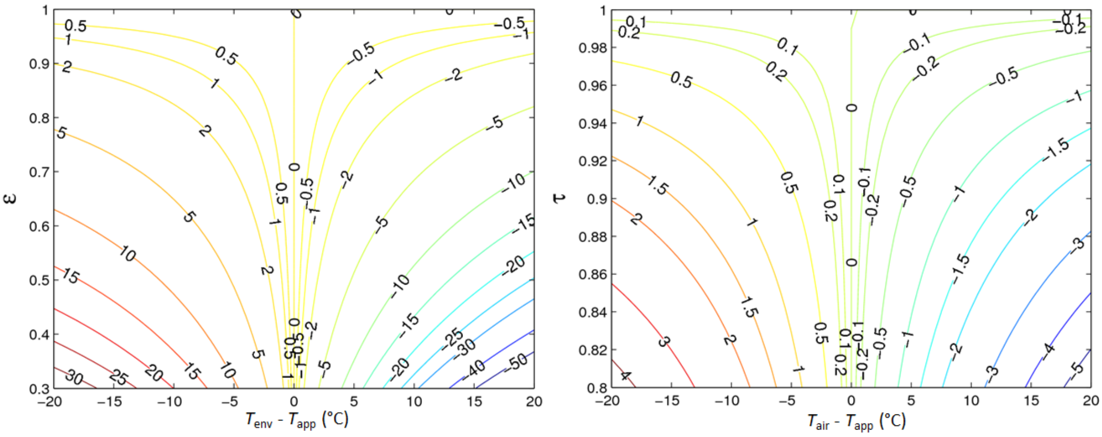

Fig. 1. *Difference (in °C) between apparent and true surface temperature as a function of possible values of influencing parameters*

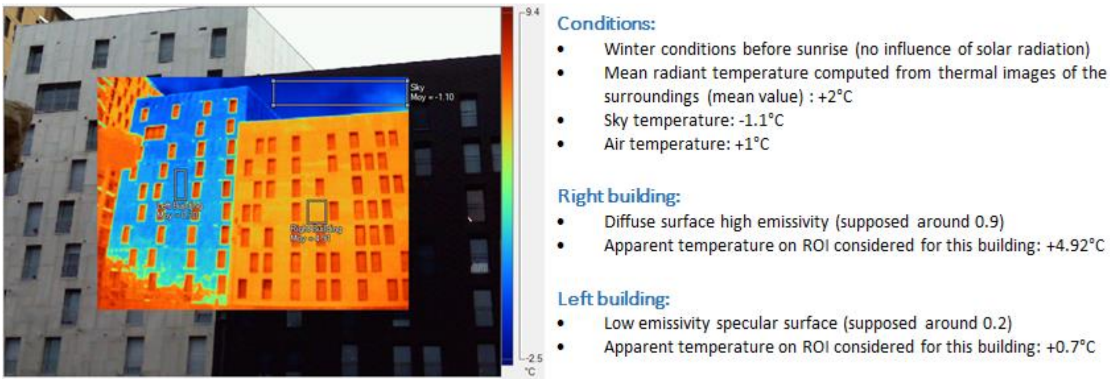

Fig. 2. *Thermal image of two adjoining buildings with different emissivity surfaces*

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