On the Suitability of Different Satellite Land Surface Temperature Products to Study Surface Urban Heat Islands

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Problem

The variety of sensors with different spatiotemporal characteristics and retrieval methodologies of land surface temperature (LST) gave rise to a multitude of approaches when analyzing the surface urban heat island effect (SUHI). There is a need for understanding the ability of sensors in capturing spatial and temporal SUHI patterns.

Materials and methods

Two cities on focus: Madrid and Paris; chosen for being large enough to be detected by both polar orbiting and geostationary sensors and for being cities already approached in previous SUHI studies. The products selection aims at increasing the diversity in temporal sampling, overpass time, spatial resolution, and LST algorithm (**Table 1**).

Table 1. Product identification and characteristics.

Product	Sensor/ Platform	Temporal Resolution	Spatial Resolution
MLST	SEVIRI/MSG	15 min	5 km
EDLST	AVHRR/Metop	Twice daily	1 km
MYD11A1 v061	MODIS/Aqua	Twice daily	1 km
MOD11A1 v061	MODIS/Terra	Twice daily	1 km
MYD21A1D and MYD21A1N v061	MODIS/Aqua	Twice daily	1 km
MOD21A1D and MOD21A1N v061	MODIS/Terra	Twice daily	1 km
GEE Landsat	TIRS, TIRS-2/ Landsat 8, 9	16 days	30 m
USGS LST	TIRS, TIRS-2 /Landsat 8, 9	16 days	30 m

SUHI intensity was computed as the difference between the temperature of the urban and the rural areas (**eq. 1**), based on the land cover provided by the Copernicus CGLS-LC100 v3.0.1 product.

$$SUHI = LST_{Urban} - LST_{Rural} \quad (1)$$

Diurnal and seasonal SUHI

In the case of Madrid, afternoon overpasses are closer to the daytime SUHI minimum, while the morning overpass are closer to the hour of the nighttime SUHI maximum. In the case of Paris, the SUHI maximum might be well represented with the afternoon overpasses, but the hour of SUHI minimum is not well captured by any of the polar orbiting sensors.

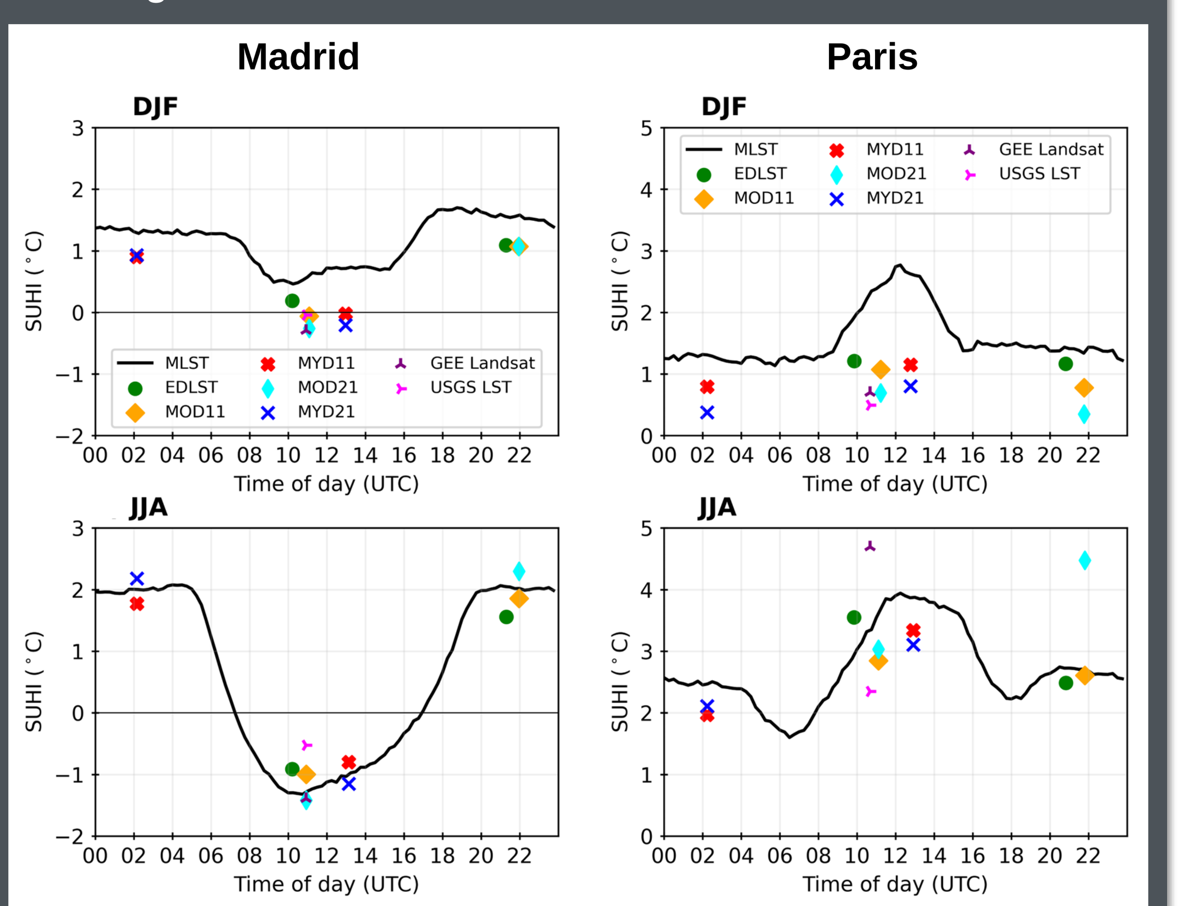

Figure 1. Diurnal cycle of SUHI for Madrid and Paris during DJF and JJA.

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Reference

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Spatial distribution of LST

The observation time associated with polar orbiting satellites may not necessarily coincide with the time of maximum and minimum of either LST or SUHI. Hour of maximum LST is generally associated to the hour of maximum incoming radiation, while the minimum of LST occurs close to sunrise when the maximum time extent without solar radiation is achieved. Therefore, it is expected that the time of LST maximum and minimum will vary throughout the year.

As expected, products with higher spatial resolution can provide more detailed maps of LST. We found that, despite the difference in resolution, the major patterns like the urban area or rivers are generally consistent between products. However, amplitudes of LSTs are very different and, in particular, contrasts between the urban a rural environment are significantly different which ultimately will result in different SUHI values.

Despite their higher resolution, polar orbiting satellites' products do not necessarily show higher contrasts between urban and rural pixels. Our results suggest that depending on the chosen product, such analysis may yield very different results. These differences in the LST patterns may be related to differences in the prescribed/retrieved emissivity that is expected to show strong variations due to the high heterogeneity of urban regions.

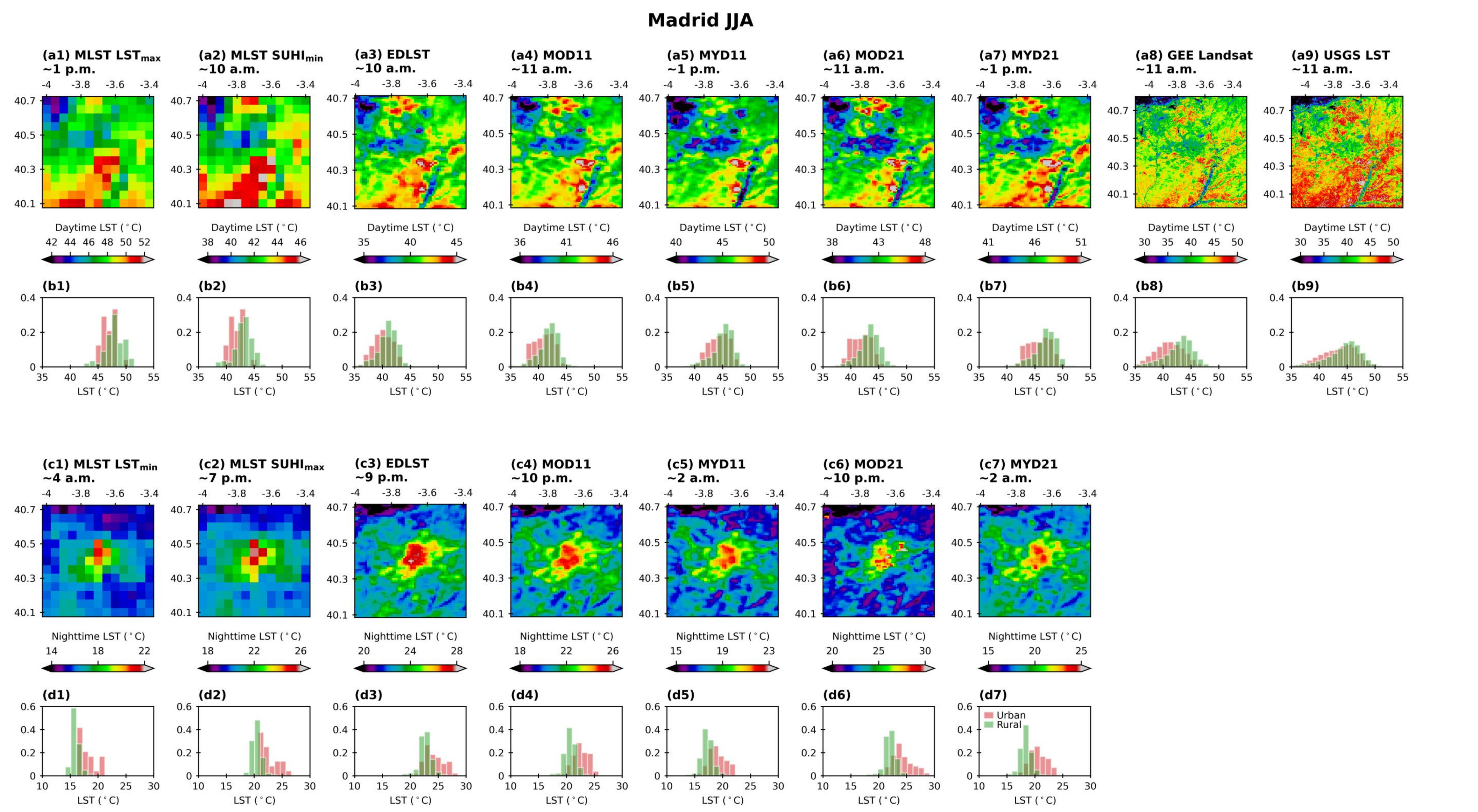

Figure 2. Mean JJA (June, July, August) LST for all products considered. a1-9) spatial pattern during daytime, in the case of the MLST the most frequent hour of LST maximum and SUHI minimum are shown; b1-9) histogram of urban and rural LST; c1-7) as in the first line but for nighttime and for the LST minimum and SUHI maximum; d1-7) as in the second line but for nighttime. Please note that colorbars are different amongst the different products to allow a better visualization of patterns, but value ranges of the histograms are the same.

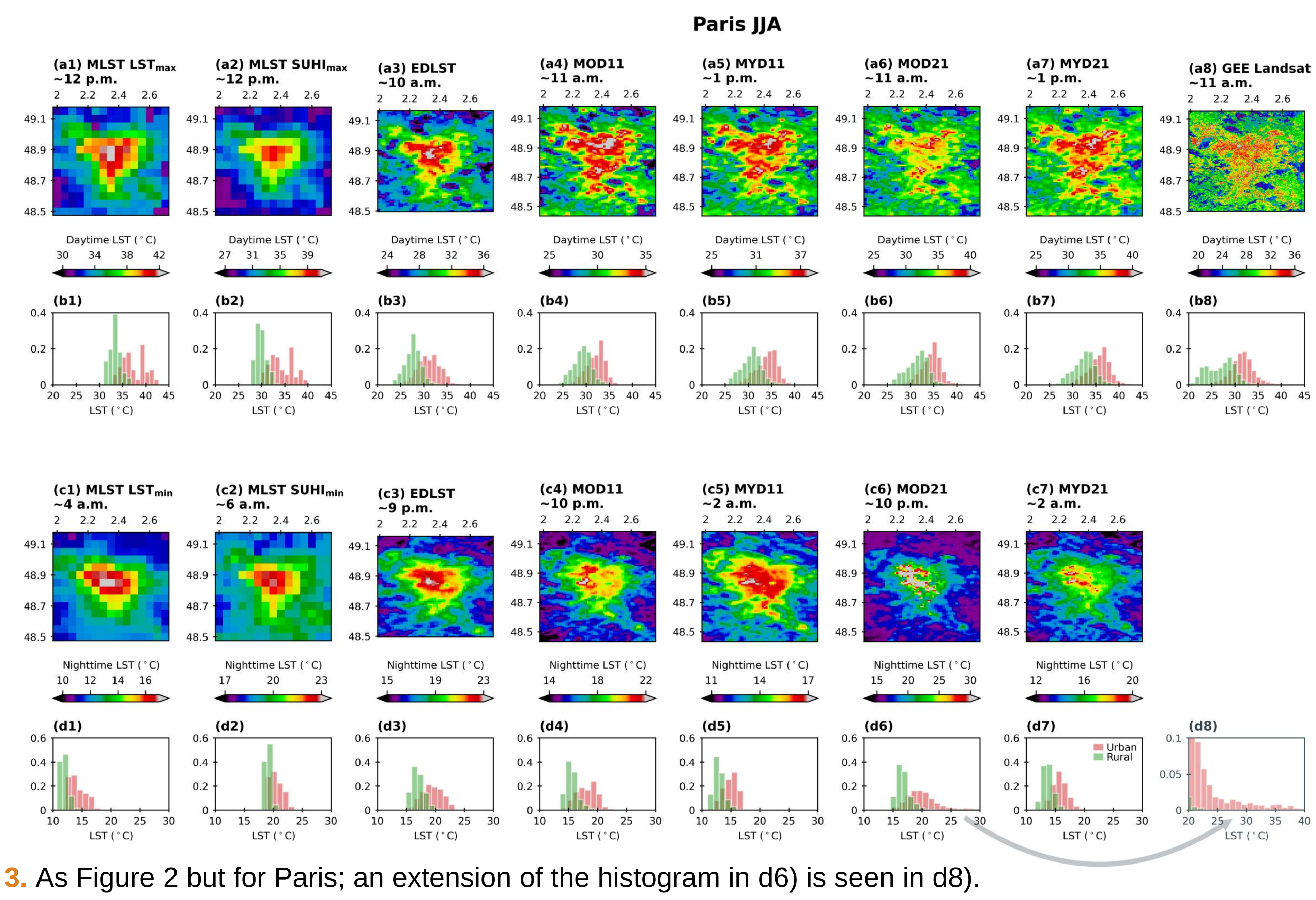

Figure 3. As Figure 2 but for Paris; an extension of the histogram in d6) is seen in d8).

Conclusion

Results show that caution must be taken when characterizing SUHI based on few observations per day, as these may not fully characterize the range of intensities, translating in different SUHI intensity or signal (positive/negative). Also, as cities and their surroundings are highly heterogeneous surfaces, low spatial resolution datasets may dampen the spatial patterns.

Analysis of the diurnal, seasonal and inter-annual variability of the SUHI also suggest low consistency on the variability as given by each product. Therefore, studies focusing on the study of SUHI based on a single product may be significantly affected by the choice of product. We also found significant biases between the products even when considering the same resolution and time of observation. Validation of LST products over urban areas is very difficult due to the high heterogeneity, therefore care must be taken when basing SUHI studies on a single LST product.

Moreover, the low sampling rate joined with observations not matching the hours of extremes for either LST or SUHI, and pixel sizes much larger than surface heterogeneity may lead to discrepancies between SUHI results and consequently, making it difficult to compare studies, even when representing the same climate and degree of urbanization.