

# Chapter 7

## The Diurnal and Nocturnal Aspects of Urban Heat Island During the four Seasons—Case of Casablanca



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### Introduction

The urban extension produces important and radical consequences for the human being, his environment, and precisely the urban climate. Among these consequences is the urban heat island (UHI), a situation where the cities' or metropolitan areas' ambient temperature is dramatically altered and becomes warmer than the surrounding rural areas [1].

If we plot an isotherm map of such a situation, the city will appear as an “island” in the background of rural temperature [2]. The UHI operates when the differences in energy and stability between urban and rural areas produce differences in the warming and cooling rates in those areas. This causes the distinctive diurnal air temperature pattern that generates the UHI, and these differences control the intensities of the UHI [3].

The UHI affects the urban quality of life through its impacts on human health, ecosystem function, local weather, and climate. There is a direct relationship between peak UHI intensity and heat-related illness and fatalities [4]. This demonstrates the importance and relevance of UHI-related studies.

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In this way studies and researches follow one another to assess the UHI causes. They show that the geometry of the city, its topography, and its thermal properties are the most important factors that induce an UHI [5–7]. The emission of anthropogenic heat and pollution affects the UHI intensity, but its impact is weaker, and it depends on the season [6, 8].

In terms of methodology, different approaches have been used to compare temperature datasets from rural and urban stations. To carry out such analysis, we considered the following criteria:

1. Rural stations must be in close proximity to the city and have similar climatic features [9].
2. Taking temperatures at several points in the city [10].
3. Studying the temporal series of temperature of stations that are engulfed by the city as it grows [11].
4. Studying the phenomenon via satellite observations [12].

Having regard to recent studies about the increase in city temperatures and the effects of environmental issues, such as global warming on health, we conduct our study on the UHI phenomenon, which is a central topic in urban climate research.

## Describing the Study Area

The city support of our study is Casablanca, a Mediterranean emerging economic capital.

Over the years this city and its region become a driving force for development, an innovation center, and an exchange hub.

The city of Casablanca is located on the Atlantic coast in the west center of Morocco; its latitude and longitude coordinates are 33.589886 north and 7.603869 west, respectively (Fig. 7.1). The area of the region of Grand Casablanca is 1117 km<sup>2</sup> [13].

The region of Grand Casablanca concentrates nearly 19% of the national urban population. Its population is increasing, as shown in Table 7.1. The rate of urbanization is close to 92% in 2008 compared with 57% nationally [12].

The spatial distribution of the population is unequal. The districts found in the heart of the city (Casa Anfa and Al Fida Mers Sultan) are the most densely populated and concentrate around 22.2% of the total population although they occupy only about 4% of the total area of the region [12].

Historically, this city built by the Zenets of Berber origin. The name Anfa refers to the port where ships used to obtain grain from neighbouring agricultural plains.

In the fifteenth century, Anfa was destroyed by the Portuguese and forgotten for almost three centuries. In the eighteenth century, Sultan Moulay Mohammad Ben Abdellah built another port where trade with Europe and America make it a privileged cramp of the Atlantic Ocean. The sultan named the city “the white house” in Spanish “Casablanca.”



**Fig. 7.1** Location of Casablanca

**Table 7.1** Development of Casablanca population, from 1960 to 2030

Year	1960 (CR)	1971 (CR)	1982 (CR)	1994 (CR)	2004 (CR)	2008 (ER)	2014 (CR)	2030 (PR)
Population of Casablanca region (millions)	1.0	1.7	2.5	2.9	3.6	3.7	4.2	5.1

Source: Statistical Yearbook of Morocco 2009

CR census results, ER evaluation results, PR projection results

Since the twentieth century, the city knows an important influence on the urban and infrastructural side [12].

The climate of the Grand Casablanca region is oceanic: mild and rainy in winter and humid and temperate in summer with the absence of frost in winter and high humidity during the year. As for rainfall, it varies from 1 year to the next [12].

## Data

The only data source for this research is satellite images from the Moderate Resolution Imaging Spectroradiometer (MODIS) aboard Aqua and Terra satellites. We chose to use the images from the Aqua satellite because of the good temporal resolution as well as the much more convenient time of passage for this study. Indeed, the Aqua satellite passes over Morocco around 1 pm and 1 am, unlike the satellite Terra which passes around 10 am and 10 pm. The study of UHI suits more to the hours of passage of Aqua. However, large spatial resolution (1-kilometer pixel) is not a problem as the study area is not a city but a region.

The day images were obtained by the services of the Royal Center for Remote Sensing (Rabat, Morocco), and the night images were obtained from NASA Land Processes Distributed Active Archive Center (LP DAAC) collections available on US Geological Survey (USGS) EarthExplorer website.

Image processing was done on ArcGIS software which generated a series of maps useful for illustration and interpretation.

## Methodology

- On the spatial scale, the study area was delineated by 20 km on both sides of the Grand Casablanca region, namely, the northeast and southwest. Thus the study area covers 345,623 Ha and has a 95 km Atlantic seafront (Fig. 7.2).
- On the time scale, we created four landmarks spread over the year. These landmarks correspond to the equinoxes and solstices: the day number 21 of the months of March, September, June, and December. This choice is relevant because it allows excluding the effect of the hot or cold climate. The study covers one decade, from 2008 to 2018, in order to exclude the effect of a cold year or a hot year and also consider the consequences of global warming.

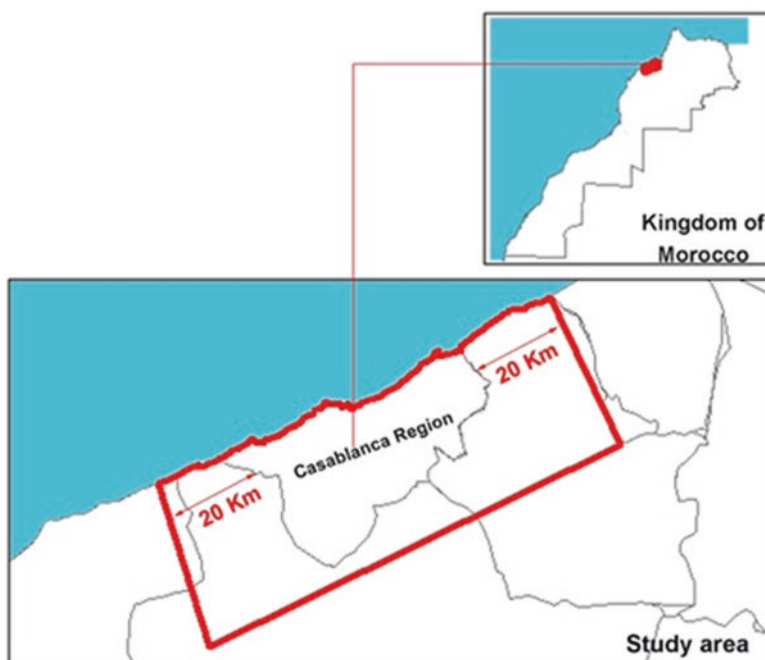


Fig. 7.2 Location of the study area

**Table 7.2** Study dates for day images

Day images	Spring equinox March 21 Julian date: 80	Summer solstice June 21 Julian date: 172	Autumn equinox September 21 Julian date: 264	Winter solstice December 21 Julian date: 355
The day of experimentation	March 25	June 27	September 28	December 25

**Table 7.3** Study dates for night images

Night images	Spring equinox March, 21 Julian date: 80	Summer solstice June, 21 Julian date: 172	Autumn equinox September, 21 Julian date: 264	Winter solstice December, 21 Julian date: 355
Image acquisition period	March 21 to March 28	June 17 to June 24	September 21 to September 28	December 18 to December 25

A small methodological arbitration was imposed against the constraints of day images. Faced with cloud masks, missing data, no coverage of the area, or unavailability of the image, the authors had to go to the next day (s) to find the information sought.

Table 7.2 shows the dates of experimentation.

For the night land surface temperature (LST), the images were extracted from MODIS product MYD11A2 V6. This product provides in each 1-kilometer pixel an average value of clear sky LSTs during an 8-day period. Selected images are given in Table 7.3.

## Results and Discussion

### *Reading Results by Day Versus Night*

The visual analysis shows that the UHI is clearly marked at night, unlike the day when it is less intense.

The north of the study area always present a heat island when compared to its surrounding environment. This island corresponds geographically to dense urban area with the highest fraction of artificial surfaces in the study area: the city of Casablanca. This observation is maintained over the four seasons as shown in Fig. 7.3.

The maximum land surface temperature (LST) at night can reach 21 °C in against 3 °C as a minimum.

This nocturnal aspect was seen in other cities and explained by the urban geometry and radiative exchange [14], enhanced cooling by evapotranspiration in the built environment [15], and/or landscaping and soil moisture availability [16, 17].

This conclusion has also been underlined by other authors [18, 19].

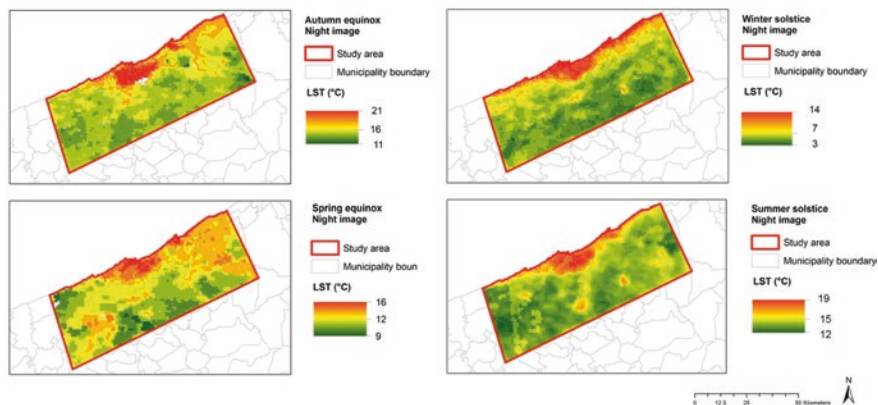


Fig. 7.3 Night images during the four seasons

### Reading Results by Seasons

Beyond the temporality day/night, we propose in the following an analysis of UHI variation across different seasons. Indeed, in autumn, the UHI is less marked in the day; the difference between the city and its periphery is not revealing, unlike at night when an island of heat appears in the most urbanized and most artificial part of the city.

In spring, the UHI is clearly marked both day and night with maximum temperatures of 32 °C in the day (1 pm) and 16 °C at night (1 am) as shown in Fig. 7.4.

In summer, due to the rising temperatures of this hot season, a large area of “hot” areas appears on the map. The difference center-periphery is less marked as the season is hot. At night the materials will continue to reflect the energy received during the day until the last hours of the night. In winter, contrary to the assumption of the predominance of the UHI over the seasons, the city appears colder than its periphery as shown in Fig. 7.5. Indeed because of its coastal facade, the sea breeze and the orientation of the city are favorable to the flow of wind in the city which allows ventilating and measuring less the effect of the UHI. At night the observation is the same. The UHI is still apparent with a clear differentiation between the urbanized city and its rural area.

### Conclusion

This work allowed crossing the phenomenon of UHI according to two temporalities: day/night, and that of the four seasons in order to skirt the subject in its annual rate evolution. We can retain from this study:

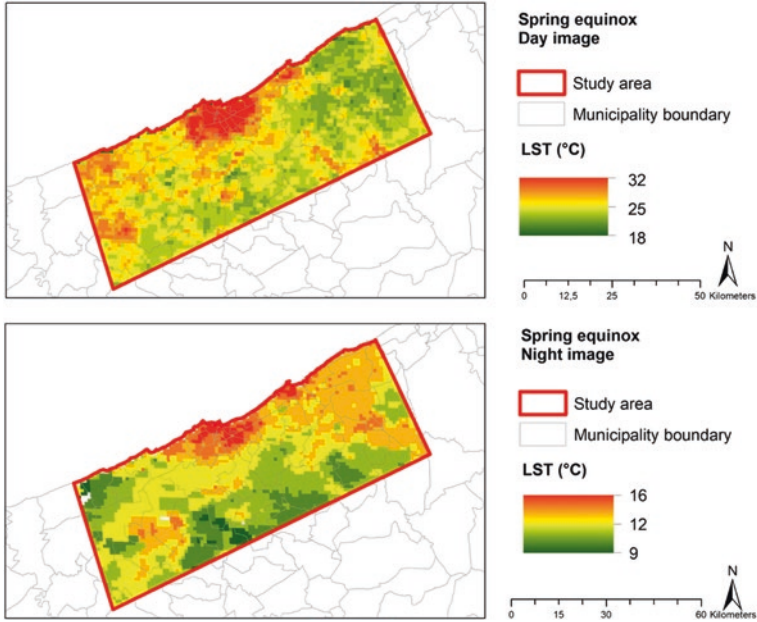


Fig. 7.4 Day and night images for a spring equinox

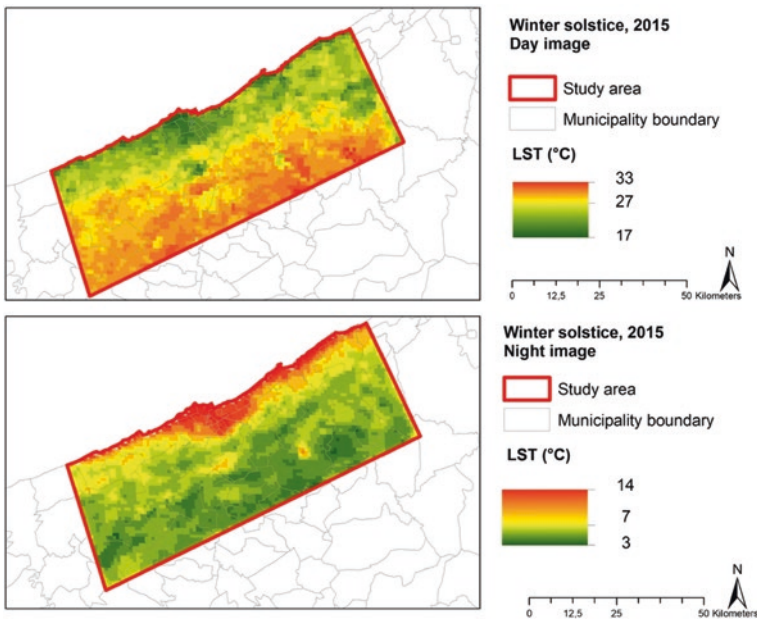


Fig. 7.5 Day and night images in a winter solstice

- In the day, the UHI is less important over the seasons unlike the night when it is a clearly visible phenomenon, marked and measured over the four seasons.
- The UHI is a phenomenon that doesn't depend on the seasons or more generally climate, so it is a phenomenon highly dependent on urbanization, forms, and materials of a city.

**Acknowledgments** The authors are grateful for the Royal Center for Remote Sensing for having provided the necessary satellite images for the study as well as an internship for an author.

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