P2.5 CHARACTERIZATION OF THE URBAN HEAT ISLAND AT BUENOS AIRES CITY

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Introduction

The difference in temperature between cities and their surrounding rural zones is the phenomenon known as the 'urban heat island' (UHI). It has been documented in extent for many cities with varying population, topography and climate regimes (Oke, 1973; Ackerman,. 1985; Moreno García, 1994; Alonso et al 2007). Many factors contribute to the urban heat island effect: anthropogenic heat sources, increased sensible heat storage and decreased evapotranspiration due to construction materials, altered energy balance leading to a positive thermal; increased long-wave radiation from the sky due to air pollution; decreased long-wave radiation loss because of the reduction of the sky view factor, among others (Oke, 1982)

Buenos Aires is one of the world's largest cities. It is located over flat terrain along the western coast of the La Plata River, a large estuary that is approximately 50 km wide near Buenos Aires. Previous studies analyzed this particular region (Barros and Camilloni, 1994; Figuerola and Mazzeo, 1998) and characterized the UHI, but this effect appears to be "changeable" with the time. In fact, Camilloni found that this UHI has a negative trend considering the yearly mean urban-rural temperature difference (period 1959-97) and considered possible changes in the stability conditions. In this work the UHI is studied for a more extensive period (1960-2007). Temperature, cloudiness, wind intensity and direction were analyzed with this propose. Changes at the stability conditions in Buenos Aires were also analyze in order to explain changes at the UHI in Buenos Aires.

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Data and methodology

The urban heat island effect in Buenos Aires is studied using data from the Buenos Aires Central Observatory (BACO - Lat: 34º 35'S Lon: 58º 29'W) in the city and from the international airport at Ezeiza (EZE – Lat: 34º 49'S; Lon: 58º 32'), 30 km southwest of the downtown area (Figure 1).

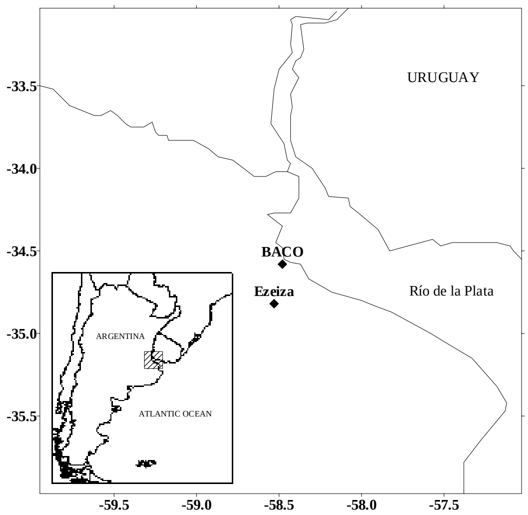


Figure 1: Location of the Buenos Aires Central Observatory (BACO, urban) and the international airport at Ezeiza (rural). (Camilloni, 1999)

There were considered the main synoptic hours 3, 9, 15 and 21 LT (local time). Buenos Aires city has other meteorological station (Aeroparque), but it is placed next to the La Plata River and this aspect needs a particular treatment. The annual mean of the hourly UHI intensity was statistically studied, for this reason, considering the temperature differences between BACO and EZE:

$$UHI = T_{BACO} - T_{EZE}$$

In order to evaluate the interannual variability of the Buenos Aires' UHI different factors that could be related to it were analyzed.

Changes in total cloud cover (in oktas), low level circulation and frequency of occurrence of atmospheric stability classes were studied. Seven stability classes, ranging from the extremely unstable class (number 1) to the extremely stable class (number 7), were calculated using a practical method proposed by Turner (1964). This method takes into account the insolation and routine surface observations of cloud and wind condition. Insolation was derived as a function of Buenos Aires geographical references, time of day and time of year.

Results

Figure 2 shows the annual mean Buenos Aires' UHI derived from the main synoptic observation hours. In this figure, a negative trend can be identified when the 48 years are considered (1960-2007). This result agrees with Camilloni (1999) that found a negative trend in the urban-rural temperature differences between BACO and EZE for the 1959-1997 period.

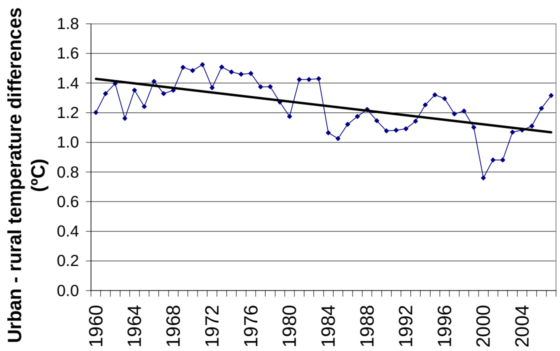


Figure 2: Annual mean urban – rural temperature differences (ºC) for Buenos Aires.

Nevertheless, the behavior of the UHI is not uniform during the day. This effect can be appreciated in Figure 3 that shows the urban-rural annual mean temperature differences corresponding to 3, 9, 15 and 21 LT. The UHI exhibits strong daily variability, with a maximum at nocturnal hours (3 and 21 LT) according to the results found by many authors for different cities of varying sizes (Oke, 1973; Figuerola and Mazzeo, 1998).

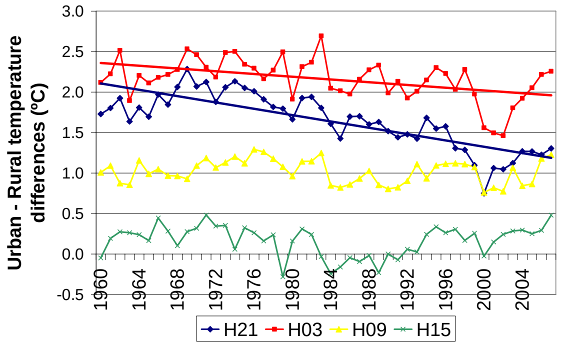


Figure 3: Annual mean urban – rural temperature differences (ºC) for the synoptic hours 3, 6, 15 and 21 LT.

The minimum differences were registered at 15 LT, hour when the maximum temperature is often registered. Furthermore, the mean difference at 15 LT reached negative values in some years. In fact, this phenomenon known as “inverse urban heat island” or “cool urban island” occurs more often with strong winds blowing from the city toward the rural area. Figuerola and Mazzeo (1998) also found and inverse heat island for Buenos Aires during the afternoon and early evening when considering a 3-year period of hourly data.

Figure 3 shows that the negative trend found for the annual mean urban-rural temperature differences (figure 2) is principally due to the nocturnal UHI. Table I summarizes the linear trends for the annual mean urban-rural temperature differences for the main synoptic hours and for the daily average derived from them. All cases exhibit negative trends, but only the nocturnal hours registered significant results.

Table I: Linear trends and explained variance for the four hours analyzed and for the daily average.

Hours (LT)	**Linear Trend (ºC/10 years)**	**Explained variance (%)**
3	**-0.09**	**22.0**
9	-0.02	3.2
15	-0.01	0.3
21	**-0.20**	**64.0**
Average	**-0.08**	**36.0**

In order to explain these trends, changes of the stability conditions were analyzed according to Turner classification. The frequency of neutral (class 4), stable (class 5, 6 and 7) and unstable (classes 1, 2 and 3) conditions were calculated using data corresponding to the main synoptic hours from BACO. Results are presented in figure 4.

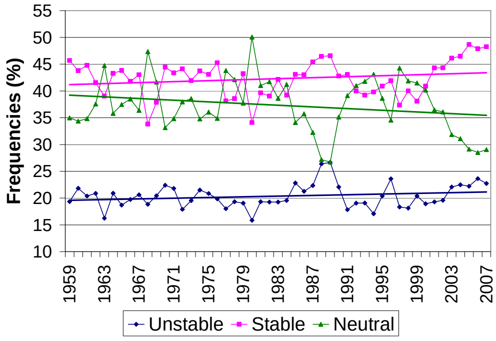


Figure 4: Annual frequency of atmospheric stability conditions in Buenos Aires (1960-2007).

Previous results showed an increase of unstable conditions more noticeable than the stable ones for the period 1959-1991 (Camilloni 1999). During unstable conditions it can be expected that the urban heat will be more easily dissipated and therefore, an increase in the frequencies of classes 1 to 3 could be related to the negative trend observed in the Buenos Aires' UHI. In this extended analysis up to 2007, the trend analysis showed also positive values in the frequency of occurrence of both stable and unstable conditions, but with the stable conditions trend larger than the unstable one (see table II). Consequently, the hypothesis of an increase in the unstable conditions as a possible cause of the negative trend found in the Buenos Aires' UHI cannot be confirmed. This is particularly true considering that the principal changes in the UHI have occurred at nocturnal hours when the method only identifies neutral and stable conditions.

Table II: Linear trends (%/year) and explained variance for Buenos Aires atmospheric stability conditions

Stability class	**Linear Trend (%/year)**	**Explained variance (%)**
Stable	0.05	3.8
Neutral	-0.08	4.9
Unstable	0.03	4.4

Different studies show that the maximum UHI is expected with calm conditions and clear sky. For this reason changes in the cloud cover and wind conditions at the BACO station were also evaluated.

The annual percentage of days with clear to low cloud coverage (0 to 2 oktas) in Buenos Aires city is presented in figure 4 for the principal synoptic hours. The trend analysis show negative values in all cases, but this characteristic is significant at the nocturnal hours (table III). These results could in part explain the diminution of the nocturnal Buenos Aires' UHI.

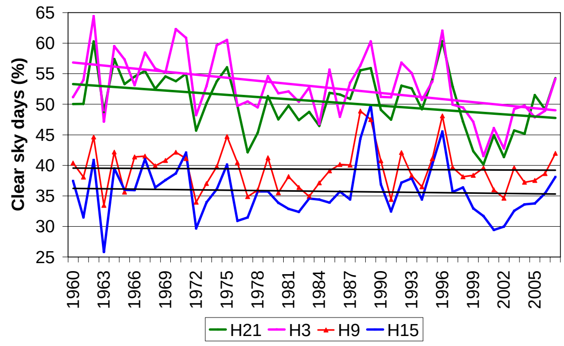


Figure 5: percentage of annual days with cloud cover less or equal 2 oktas at BACO station.

Table III: Linear trends of clear to low cloud coverage and explained variance for the nocturnal hours

Hours (LT)	**Linear Trend (ºC/10 years)**	**Explained variance (%)**
3	-0.17	20.6
21	-0.12	12.7

The intensity and direction of wind also influence the form and intensity of the UHI. Figure 6 shows the annual time series of frequency of calm conditions at BACO for the nocturnal hours. Although both series show strong interannual variability, negative trends can be identified probably contributing to the negative trend found for the 3 and 21 LT urban-rural temperature differences.

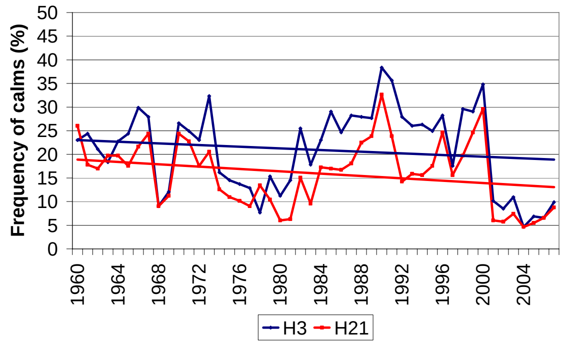
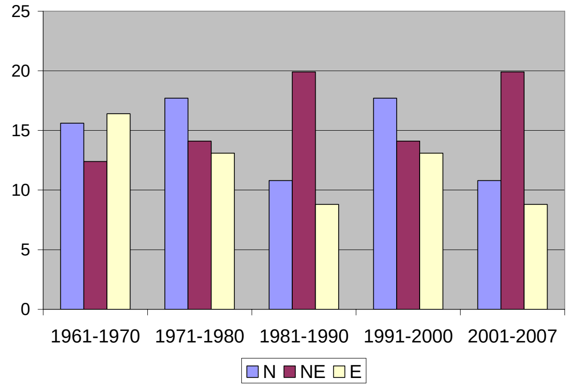


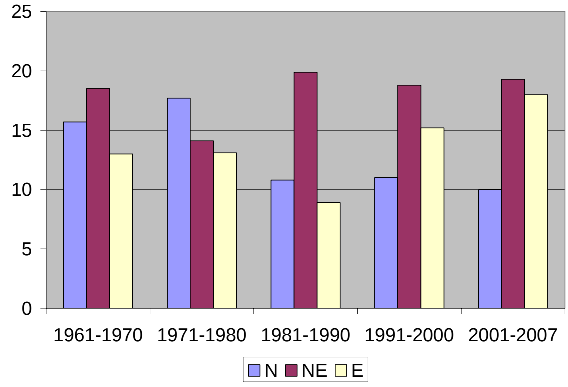
Figure 6: Annual frequency (%) of calm conditions at BACO for nocturnal hours.

Observed changes in the surface circulation conditions were also considered to evaluate possible reasons of the negative trend in the nocturnal Buenos Aires' UHI. Previous studies showed a change in the low level regional circulation associated to enhanced north-eastern winds in Buenos Aires and La Plata River (Camilloni, 1999; Simionato et al., 2005; Di Luca et al. 2006). Camilloni (1999) associated these changes in the frequency of NE winds at the urban station with the negative Buenos Aires' UHI trend. Figure 7 shows the decadal frequency (except of a last period with 7 years) of surface winds of the N-E sector at OCBA and EZE that confirms the increase of occurrence of NE winds at both stations. This result indicates that the rural station could be more frequently affected by the urban plume due to its relative position 30 km southwest of the downtown area.

Figure 7: Decadal frequencies (%) of wind direction at BACO (a) and EZE (b)



(a)



(b)

Conclusions

Buenos Aires is one of the largest cities of the world. Although it population has been growing steadily during the last decades it was found the annual mean UHI and particularly the nocturnal annual mean UHI exhibits negative linear trends for 1960-2007. Changes in different parameters were explored to evaluate its possible relationship with these negative trends: atmospheric stability, cloud cover and wind intensity and direction. Results indicate that the negative trends in the annual mean nocturnal UHI could be in part explain by a reduction of clear sky conditions and calm frequency at the urban station and by a change in the low level regional circulation with larger frequencies of the urban heat plume affecting the rural station. The observed changes in the stability conditions with an increase in the occurrence of both stable and unstable classes could not explain the changes in the Buenos Aires' UHI. Nevertheless, this last result could be related no to physical processes but to the method considered for the computation of atmospheric stability.

Acknowledgements
The authors are grateful to Servicio Meteorológico Nacional for providing the meteorological information used in the present study.
This work was supported by the University of Buenos Aires under Grant. X033

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