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THE CHANGING URBAN CLIMATE OF PORTO, PORTUGAL

The long term climatological data for the Serra do Pilar station, on a high bluff immediately to the south of the Duoro River in the centre of the metropolitan region of Porto, reveal that the minimum February temperatures for the 30 years 1960-1989 are 0.8°C higher than those from 1931-1960. Similarly October minimum temperatures are 0.6°C higher while those for March, April and May are around 0.7°C lower. Mean monthly rainfall totals for the periods September to February and April to June are for 1960-1989, while those for the other months (February, July and August) are lower. While general estimates of annual mean sea level temperature changes in the region of Porto for the period 1950-70 show no clear trend for those for the Port of Leixoes, close to Porto show distinct upward trends in the years 1970-1990, especially for the months November, December, January, March and April. Given these long term trends and some evidence for warming in the 30 years prior to 1990, closer examination of all available climatic data in the Porto Metropolitan area is required to ascertain both whether there is a rise in temperatures in the urban area and whether any rise is due to global warming or to the urban heat island effect.

In the period 1970-1989, the highest minimum temperatures for six observing stations within the urban area of Porto occur in the decade 1980-1989. The highest minimum temperatures in these twenty years in the months of May, July and December occurred in 1988 or 1989. Some of the climatic stations within the city demonstrate clear evidence of being least cold in 1988 and 1989. The majority of the coldest temperatures observed fell between 1970 and 1980. A clear trend of a decrease in minimum temperatures in the urban area emerges over the last twenty years. Regression analysis of minimum temperatures against time all exhibit an increasing trend, confirming that perhaps this increase in minimum temperatures is caused by factors external to the city. Stations within the built-up area and stations on the fringe of the city all exhibit this upward trend. The trends in Porto thus agree with the general statement by Flohn and Fantechi (1984) that European cities have become about 1° warmer since beginning of the century.

Monthly mean maximum temperatures show a similar trend, 51 out of the 50 highest monthly mean maxima occurring in the period 1980-1989. 45% of these highest values occurred in 1988 or 1989. Although the trend for a steady increase in monthly maximum temperatures is less clear than for the minimum temperatures, the overall upward trend appears to be due to a combination of the influence of the growth of the metropolitan area of Porto and global warming as a whole.

Precipitation exhibits much more variation than temperature. Running means and regression analysis for April precipitation at the San Gens, Serra do Pilar, Boa Nova and Pedras rain gauge sites all exhibit a steady upward trend through the two decades.

November totals show a distinct difference between the first and second decade of the period analysed. However, the trends in other months are less clear.

Within the urban area, a clear difference in climatic trends arises with the distance of a given station from the sea. Coastal stations are greatly affected by the presence of ocean water and show less response to urban influences, particularly in winter. In detail, formation of an urban heat island in the hilly terrain of Porto with the deep valleys of the Douro and its tributaries is intimately related to the prevailing weather systems. Using a combination of fixed thermometers and traverses, a heat island with a rural-urban temperature difference of as much as 6°C was found to develop immediately to the north of the main Douro bridge in the centre of the city. The shape of the form of this heat island varied with weather conditions, but it was best developed and persisted longest under anti-climatic conditions. Behaviour of the heat island could be closely related to patterns of traffic and human activity, one of the most intensive heat island occurring during a period of late-night shopping immediately before Christmas.

Analysis of the urban climate of Porto clearly demonstrates the influence of proximity to the sea, of relief and of episodes of energy consumption through human activity. However there are a both global warming and urban expansion influences on the climate of the metropolitan area and these factors illustrate how important consideration of urban, local and micro-climate is in planning for the sustainable development of cities.