

INTERDECADAL VARIABILITY OF TEMPERATURE EXTREMES IN ARGENTINA: A PEAKS-OVER-THRESHOLD FIT

Bárbara Tencer ^{1*}, Matilde Rusticucci ^{1,2}

¹ Departamento de Ciencias de la Atmósfera y los Océanos, FCEN, UBA - CONICET, Buenos Aires, Argentina

² Centro de Investigaciones del Mar y la Atmósfera (CIMA) UBA/CONICET

1. INTRODUCTION

The frequency of occurrence of extreme temperature events has been changing all over the world during the last century. Significant increasing trends in the percentage of warm nights and decreasing trends in the percentage of cold nights were observed at many stations (Alexander et al, 2006). In Argentina, the probability of occurrence of annual warm extremes of maximum temperature has decreased in the last decades while an increase is noticed in minimum temperature warm extremes at some stations (Rusticucci and Tencer, 2008).

Interdecadal variability also has an influence on the frequency of occurrence of extreme events. Kenyon and Hegerl (2008) show that temperature extremes are substantially affected by large-scale circulation patterns, such as the El Niño-Southern Oscillation, the Pacific interdecadal variability and the North Atlantic Oscillation. Extremes show distinct regional patterns of response to modes of climate variability, which influence the shape of the daily temperature distribution beyond a simple shift, often affecting cold and warm extremes and sometimes daytime and nighttime temperatures differently.

The main purpose of this study is to evaluate observed changes in return periods of temperature values that exceed a specified threshold at stations from Argentina, during the period 1941-2000. Extreme value theory provides a useful tool to analyse these possible changes. Since daily data are available, a peaks-over-threshold model is chosen because it uses more information than block maxima models.

2. DATA AND METHODOLOGY

Daily data of maximum and minimum temperature from 5 stations in Argentina over the period 1941-2000, provided by the Servicio Meteorológico Nacional (National Weather Service), were used in this study: Observatorio Central Buenos Aires, Buenos Aires (OBA, 34.58° S, 58.48°W); Pergamino, Buenos Aires (PGM, 33.93° S, 60.55° W); Pilar, Córdoba (PIL, 31.66°S, 63.88°W); Santa Rosa, La Pampa (SRS, 36.56° S, 64.26° W); San Miguel de Tucumán, Tucumán (TUC, 26.80° S, 65.20° W).

Anomalies respect to a mean annual cycle were calculated so that data were comparable between stations and throughout the year. Based on the series of anomalies, two warm extremes were defined as values over a specified threshold: high maximum temperature (HTx), which are all cases of anomalies of daily maximum temperature (Tx) exceeding a fixed threshold, and high minimum temperature (HTn), which are all cases of anomalies of daily minimum temperature (Tn) over a fixed threshold.

Thresholds were selected so that 5% of the total data set were considered as extremes for the peaks-over-threshold model fit. Statistical independence of the selected events was ensured by guarantying a minimum separation of 4 days between extreme events (Brabson and Palutikof, 2002).

The statistical model used in this study is the Generalized Pareto Distribution (GPD), which was fitted to the sample of extremes defined above. Once parameters are estimated using the method of maximum likelihood estimation, return values are calculated. A 100-yr return value is expected to occur, on average, once every 100 years. However, this information is only true under the assumption of a stationary process. This assumption is not always valid for temperature records either because of a climate shift or the presence of trends due to long term climate changes. Therefore, in this paper the daily temperature series are divided into three 20-yr non-overlapping periods: 1941-1960, 1961-1980 and 1981-2000, with the aim of analysing the

* *Corresponding author address:* Bárbara Tencer, Departamento de Ciencias de la Atmósfera y los Océanos, FCEN, Universidad de Buenos Aires, Ciudad Universitaria, Pabellón 2, 2º piso, 1428, Buenos Aires, Argentina; e-mail: btencer@at.fcen.uba.ar

interdecadal variability. Extremely warm days defined as those in which temperature exceeds a fixed threshold for each period, are modeled by GPD. Following Coles (2001), the GPD for warm extremes is described by

$$H(y) = 1 - \left(1 + \frac{\xi y}{\sigma}\right)^{-1/\xi} \quad (1)$$

defined on $\{y : y > 0 \wedge (1 + \xi y/\sigma) > 0\}$, where $H(y)$ is the distribution function of the exceedances over a threshold u conditional on $X > u$, $y = X - u$, μ and σ are the location and scale parameter, respectively. The N -yr return level is the value which is exceeded on average once every N years and is defined by

$$z_N = u + \frac{\sigma}{\xi} \left[(N n_y \tau_u)^\xi - 1 \right] \quad (2)$$

where n_y is the number of observations per year and τ_u is the probability of an individual observation exceeding the threshold u . Therefore, changes in return levels imply changes in the frequency of occurrence of extreme events: for a fixed return period, return values are expected to increase if that particular event happens to occur more often, or decreased if the frequency of occurrence has suffered a reduction.

Once the parameters were estimated for all stations, variables and periods, quantile plots (QQ plots) were performed to verify the goodness of the GPD fit in each case. All fits show a good level of agreement with the empirical estimates (figures not shown).

3. RESULTS

Thresholds chosen for HTx at each station and period are shown in Figure 1. It can be seen that thresholds for each period are smaller than, or equal to, the previous one. Since thresholds correspond to the 95th percentile, this implies that Tx is decreasing at these stations, which is consistent with results found by Rusticucci and Barrucand (2004) and Rusticucci and Tencer (2008). Thresholds vary less than 2°C from the first period to the last at all stations, except at TUC where the variation is almost 4°C. On the contrary, variations between periods for thresholds of HTn are less than 0.5°C (Figure 2), denoting less interdecadal variability for minimum temperature extremes. Since extremes are based on temperature anomalies, thresholds are

comparable between extremes. At all stations thresholds are of the same magnitude, except for PIL and TUC, where HTx has greater thresholds than HTn. This implies that maximum temperature extremes in PIL and TUC are more intense than minimum temperature extremes.

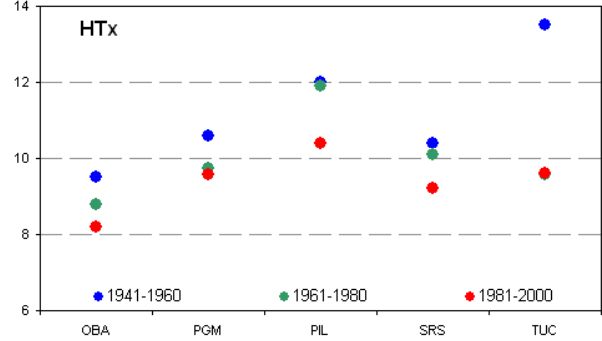


Figure 1. Thresholds (in °C) chosen for HTx at stations OBA, PGM, PIL, SRS, TUC for each period: 1941-1960 (blue), 1961-1980 (green), 1981-2000 (red).

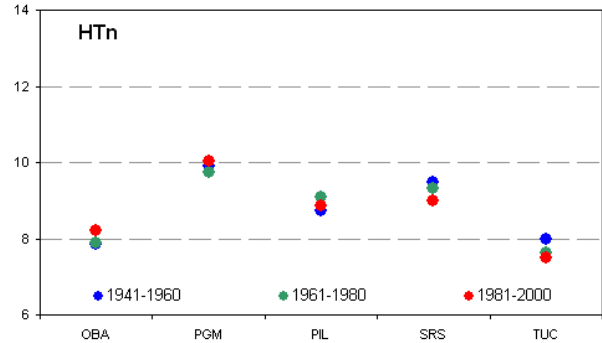


Figure 2. Thresholds (in °C) chosen for HTn at stations OBA, PGM, PIL, SRS, TUC for each period: 1941-1960 (blue), 1961-1980 (green), 1981-2000 (red).

Figure 3 shows 30-yr return values for HTx, together with their 95% confidence intervals. It can be seen that PIL and TUC show the greatest return values for almost every period, which is consistent with the thresholds chosen. At all stations, return values from the period 1941-1960 to 1961-1980 decrease, but they increase in the last subperiod, the only exception being SRS where the increase in the most recent period is not seen. This increase in the last period implies a higher frequency of occurrence of maximum temperature warm extremes. However, confidence intervals indicate that during this period there is also more uncertainty in the estimates due to more variability in the series of extremes, as it is evident from Table 1, where standard deviation for each period and station are shown. This behaviour in the 30-yr return value was also found in return values for different return periods (figures not shown).

Return values for HTn show a similar behaviour (Figure 4): they decrease from the first period to the second, but increase in the last subperiod. Again, at SRS this increment in the last subperiod is insignificant, although it becomes more evident for greater return periods (not shown). Return levels at PIL do not increase during the last subperiod for return periods greater than 30 years, and they even decrease slightly for small return periods. As it is evidenced by the magnitude of the standard deviation (Table 2), HTn has less variability than HTx, and therefore confidence intervals are smaller.

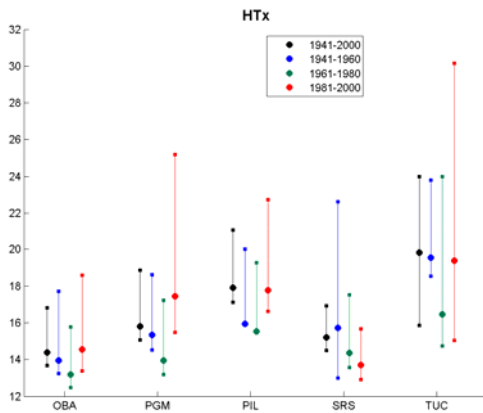


Figure 3. 30-yr return values and 95% confidence intervals for HTx, at stations OBA, PGM, PIL, SRS, TUC for each subperiod: 1941-1960 (blue), 1961-1980 (green), 1981-2000 (red), and the complete period 1941-2000 (black).

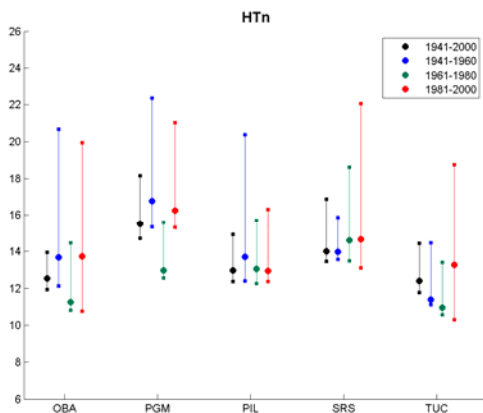


Figure 4. 30-yr return values and 95% confidence intervals for HTn, at stations OBA, PGM, PIL, SRS, TUC for each subperiod: 1941-1960 (blue), 1961-1980 (green), 1981-2000 (red), and the complete period 1941-2000 (black).

	OBA	PGM	PIL	SRS	TUC
1941-1960	1.27	1.24	1.20	1.41	1.60
1961-1980	1.05	1.11	1.08	1.08	1.67
1981-2000	1.54	1.95	1.94	0.95	2.26

Table 1. Standard deviation of exceedances over the threshold (in °C) for HTx for each period and station used in this study.

	OBA	PGM	PIL	SRS	TUC
1941-1960	1.41	1.71	1.25	1.23	0.97
1961-1980	0.91	0.89	0.95	1.28	0.93
1981-2000	1.42	1.64	1.09	1.37	1.44

Table 2. Standard deviation of exceedances over the threshold (in °C) for HTn for each period and station used in this study.

4. DISCUSSION

Two warm extremes have been defined as values that exceed a specified threshold, chosen as the 95th percentile of the daily series of temperature anomalies: HTx, based on maximum temperature anomalies; and HTn, based on minimum temperature anomalies. Return levels were calculated by fitting a peaks-over-threshold model to the excesses over the threshold. Parameters of the GPD were estimated at five stations from Argentina using the method of maximum likelihood estimation. In order to analyse the interdecadal variability of temperature extremes, the GPD has been fitted to three 20-yr non-overlapping periods: 1941-1960, 1961-1980 and 1981-2000, as well as to the complete period 1941-2000. All fits showed a good level of agreement with empirical distributions, according to QQ plots.

Interdecadal variability appears to have a great importance when analysing extreme temperature events. Return levels for both extremes (HTx and HTn) show that there is a decrease in the frequency of occurrence of warm extremes from the first period to the second, followed by an increase in the last period. Rusticucci and Tencer (2008) found that warm annual extremes of maximum temperature become less frequent after the 1976-77 climatic shift, while warm annual extremes of minimum temperature increase the frequency of occurrence at some stations. These results are based on warm annual extremes which are restricted to the most warm extreme event, almost always a summer event. However, the analysis of extreme events using a Pareto distribution uses more information because it is based on daily data. In

this study, we fitted a GPD to daily anomalies and therefore extreme events happening any time during the year are included in the analysis.

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