Observed Trends and Changes in Temperature Extremes over Argentina

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25 March 2003 and 13 April 2004

ABSTRACT

In this note, changes in temperature extremes over a 40-yr period are analyzed, based on daily minimum and maximum temperatures over Argentina. Trend analysis was performed on seasonal means, standard deviations, and extremes (5th and 95th percentiles) over the 1959–98 period. The strongest (positive) changes over time occurred in mean summer minimum temperature, whereas the standard deviation decreased. Mean maximum temperatures mostly decrease over time in summer over northern Argentina, but they increase in Patagonia (southern Argentina). Generally, negative trends were obtained in the number of cold nights and warm days per summer, while the number of warm nights and cold days has increased at certain locations. Patagonia shows many stations with an increasing number of warm days and nights in winter and a decreasing number of cold days and nights in summer. The summer mean temperature is more sensitive to extremes than the winter one. In summer, the increase in mean temperature is more strongly related to the increase in the number of warm days and nights than to a decrease in the number of cold days and nights. In winter, the region with the highest correlation was found in Patagonia, while in the most productive area (La Pampa, Argentina), very little or nonsignificant association exists between mean temperature and the occurrence of warm or cold days.

1. Introduction

There are fewer studies of regional variability in climatic extremes compared to studies of changes in climatic means, although some regional assessments have been made. The determination of climatic trends of extreme events is more difficult than for average variables (Nicholls 1995). Detailed studies presented on the trends of extremes do not include results for South America, particularly for Argentina (Easterling et al. 2000; Frich et al. 2002). As recommended by Karl and Easterling (1999), continued documentation of climate trends, particularly in terms of climate extremes, will be critical for decision makers in the future as they deal with environmental changes and their impacts.

Argentina is characterized by a wide variety of climates: from tropical to polar and from dry to wet (Easterling et al. 1999). Rusticucci and Vargas (2001) present an analysis of the interannual variability of warm and cold spells in the north of Argentina. The number of extreme spells per year shows low-frequency variability plus a biennial variability, which is more important in its intensity than in its persistence and occurs in summer rather than in winter. The extreme temperature events in Argentina show high correlation with the sea surface temperatures; they are closely related to the warming and cooling of the coastal waters in the South Atlantic and South Pacific (Rusticucci et al. 2003) as well as ENSO variability (Rusticucci and Vargas 2002).

The frequency of extreme events depends not only on the rate of change of the mean of a selected variable but also on whether there are changes in other statistical parameters, which determine the distribution of the variable. The International Panel on Climate Change (IPCC; Houghton et al. 2001) assumes that changes in the relationship between mean temperature and standard deviation are of potential importance to climate change and suggests that in the future the frequency of extreme temperature events and their magnitude will increase. As this postulate is based on normal symmetric distributions, and since both extremes of the distributions produce different effects on the society, an approach to the problem may either be done through assumptions of different scenarios, with changes in different parameters (Barrow and Hulme 1996), or by analyzing past

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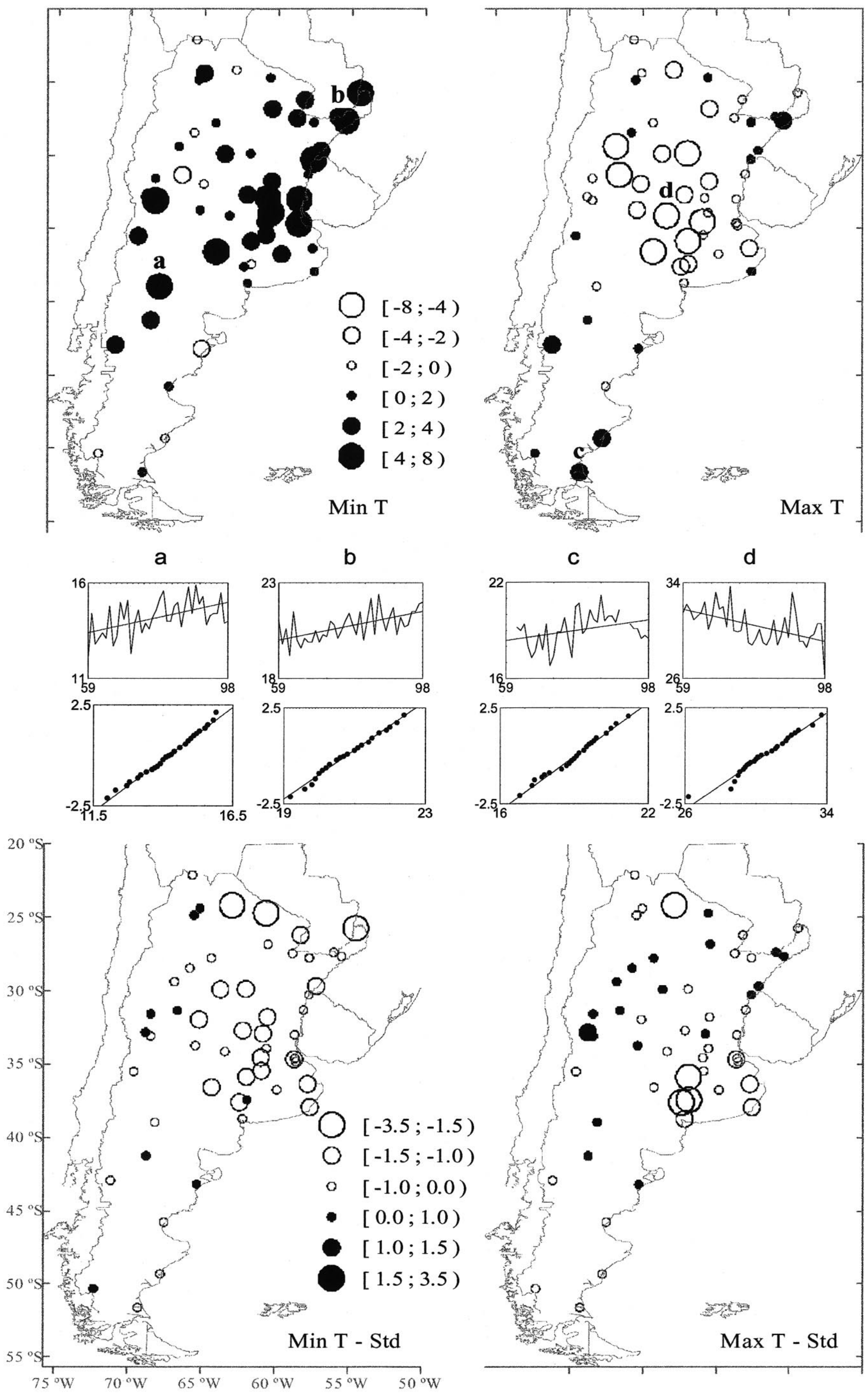

FIG. 1. Trends [°C (100 yr)$^{-1}$] of (top) minimum and maximum mean seasonal temperatures and (bottom) standard seasonal deviation in summer (1959–98). Stations with positive (negative) trends are shown with solid (open) circles. The diameter of the circles is proportional to the trend. The values of $|\beta| < 2$°C (100 yr)$^{-1}$ are generally not significant at the 5% level. (middle) Time series and normal probability plots for some sample locations of mean (a), (b) MinT and (c), (d) MaxT.

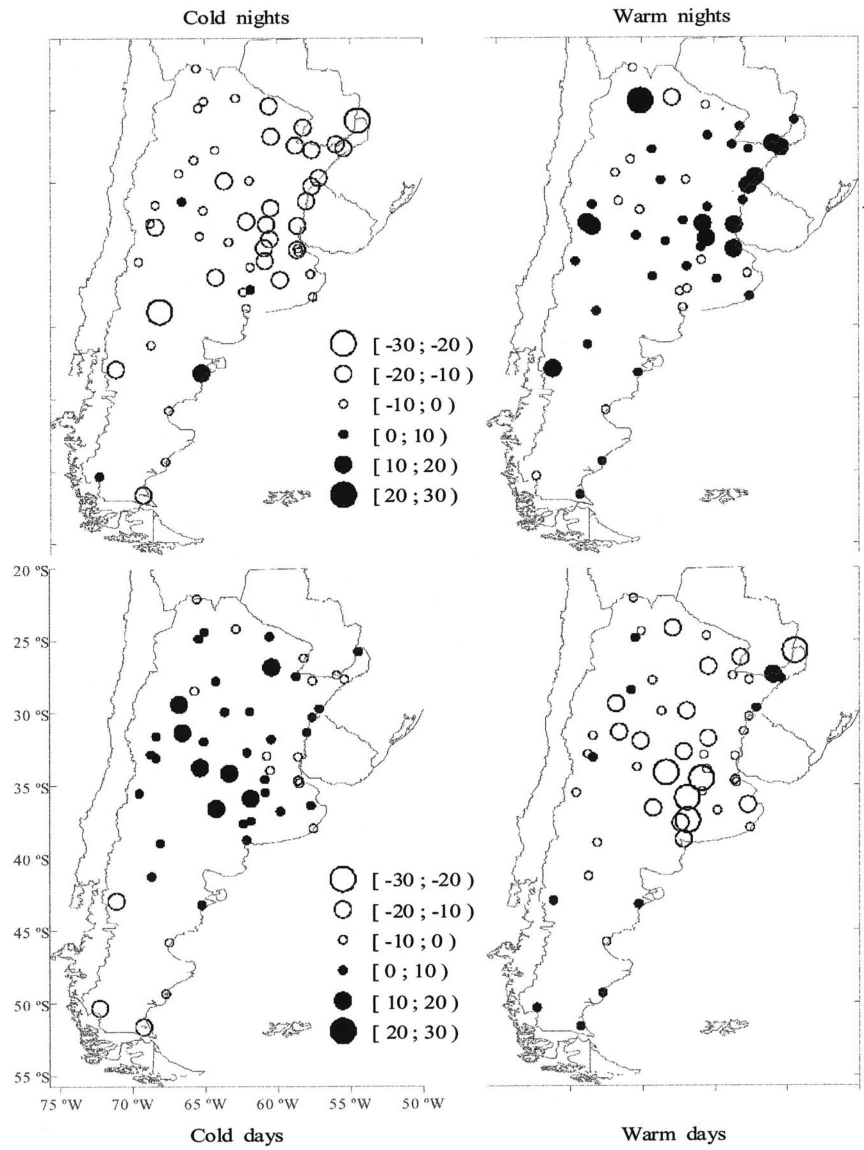

FIG. 2. Trends of number of (left) cold (5th percentile) and (right) warm (95th percentile) (top) nights (minimum temperature) and (bottom) days (maximum temperature) in summer. Stations with positive (negative) trends are shown with solid (open) circles. The diameter of the circles is proportional to the trend. The values of $|\beta| < 10\%$ days yr^{-1} are generally not significant at the 95% level.

changes. Models should be extensively validated, and observational studies should be carried out in the fine temporal scale in which the extremes occur (Knappenberger et al. 2001). The use of station data requires an intensive quality control, mainly for extremes studies. On the other hand, the National Centers for Environmental Prediction–National Center for Atmospheric Research (NCEP–NCAR) reanalysis data have to be used with caution for studies that consider the magnitude of extreme temperatures (Rusticucci and Kousky 2002).

In order to capture the temporal patterns of observed temperature change, in this exploratory study, the trends of the mean, the standard deviation, and the extreme maximum and minimum daily temperatures over Argentina are shown, based on a deeply quality-controlled stations database. Also, the existing relation between mean seasonal values and the occurrence of extremes in each season is analyzed, which can provide a historical analog that can be used to estimate the range of possible responses of the climatic system to global warming.

2. Data and methodology

An exhaustive data-quality control was performed, based on data provided by the Servicio Meteorológico Nacional (National Weather Service) on daily maximum

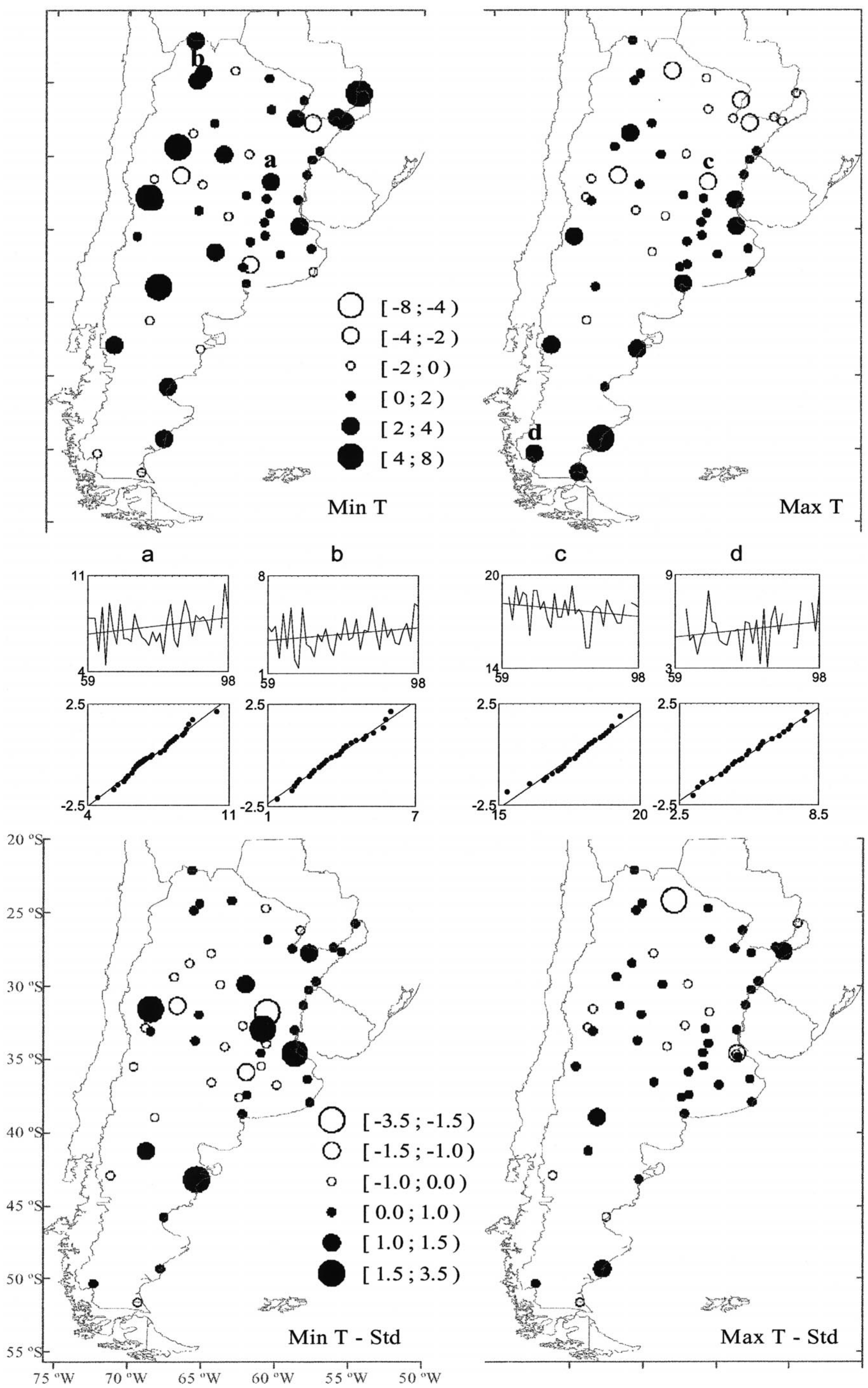

FIG. 3. Same as in Fig. 1, except for winter.

and minimum temperatures throughout the country, for the period 1959–98. This thorough analysis was carried out according to the guidelines set out in the control guide of quality surface climatic data published by the World Meteorological Organization (WMO; Abbott 1986) in the World Climate Data program. As detailed in Rusticucci and Barrucand (2001), a check for consistency in station location is carried out, eliminating those series when stations had changed in location, and only those series that turned out to be 75% complete over the whole period were considered. It must be pointed out, however, that the majority of series used are over 90% complete. The quality control was divided into three stages: data reading and format control, suppression of indisputable errors (cases with maximum temperature below the minimum, temperature sequences

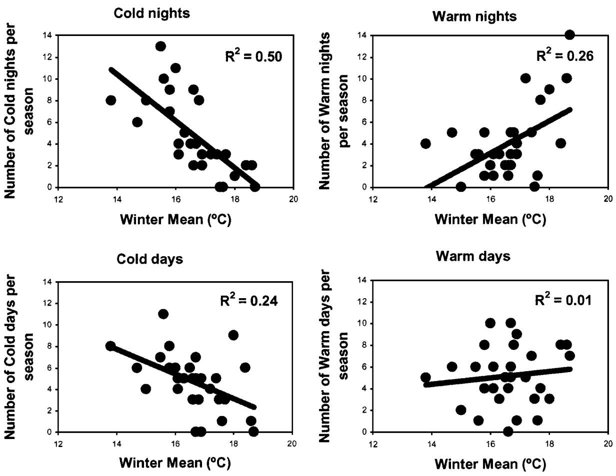

FIG. 4. Linear regression analysis between the number of extreme days per winter and the mean temperature value in winter for (top left) cold nights, (bottom left) number of cold days, (top right) warm nights, and (bottom right) number of warm days at General Paz Station, Corrientes, Argentina (27°45′S, 57°38′W). The R^2 value is shown in each graph.

of unrealistic 0°C temperatures and outliers), and finally, controls over differences in temperature between two consecutive days. This last analysis is based on the persistence of the atmospheric data in order to detect other errors, such as typing errors.

It was decided to check cases in which the interdiurnal difference in two consecutive days was higher than 5 times its standard deviation, for each month. These cases, which statistically had a very low probability of occurrence, were observed at several stations, where they were often detected at maximum temperatures. They were analyzed in detail and in some instances these cases were determined not to be erroneous, and the large interdiurnal differences were associated to synoptic phenomena. This surmise was more clearly seen in a particular case on 25 August 1996. On that day, 10 stations had a difference in maximum temperature when compared to the previous maximum temperature, which was above 5 times the standard deviation (differences of up to 20°C). Based on regional consistency, this case was not considered an error. Therefore, special care must be taken when establishing acceptable ranges for consistent information. Finally, stations that might have been affected by significant urban growth were not considered in the sample, so that 54 out of a total of 102 initially considered stations met the inclusion criteria.

The intraseasonal standard deviation was computed from daily data. Moberg et al. (2000) show that the intramonthly standard deviation is a measure of daily variability that is well correlated with all the other measures they presented. As it is also a widely used measure of variability and easy to interpret, they conclude that it is a good general measure of daily temperature variability.

The trends of seasonal means, standard deviations, and extremes are evaluated for summer [December–January–February (DJF)] and winter [June–July–August (JJA)]. The significance of the lineal slope was considered at 5% (Hoel 1971), allowing the comparison to all other cited studies. Considering that a great number of tests were applied to several variables, and knowing that a correlation among variables exists, this significance limit should be considered as a lower limit (Wilks 1995; von Storch and Zwiers 1999).

Extremes are defined as follows: ‘‘summer (winter) cold night’’ if the minimum temperature is found below the 5th percentile calculated for all days within summer (winter) and ‘‘summer (winter) warm night’’ if it exceeds the 95th percentile of the same variable. Similarly, ‘‘cold days’’ (‘‘warm days’’) are defined as days when the maximum temperature is found within the 5th (95th) percentile of daily seasonal maximum temperature. For interstation comparability, the use of percentile values is considered more adequate to refer the changes under study to local values. To overcome the problem of missing data, the percentage of extreme days or nights per season is calculated, so the number of days are ‘‘normalized,’’ and this variable is used; the variable is called number of days per season for simplicity. Finally, in order to estimate the relationship between the mean seasonal value and the extremes, the regressions between mean seasonal temperature values and the number of these extreme daily values are examined.

3. Results

a. Trends in summer (DJF)

In Fig. 1 (top), the sign and magnitudes of the slopes (β) related to mean minimum (MinT) and maximum temperatures (MaxT) are shown. To expose some characteristics of the observations, some trends for some sample locations are shown, together with their normal probability plots. An estimated β value of at least 2°C $(100\ \mathrm{yr})^{-1}$ is required to obtain significance at the 5% level. Different patterns in each variable are clear. The vast majority of the stations throughout the country present a significant positive linear trend in the mean MinT in summer (see, e.g., Figs. 1a,b), with values reaching up to 6.2°C $(100\ \mathrm{yr})^{-1}$. In contrast, three separate regions emerge from MaxT: the central region (including La Pampa, Argentina), with large negative trends (see, e.g., Fig. 1d); the south (Patagonia, Argentina, south of 40°S), with positive trends (see Fig. 1c); and the north (subtropical climate), with positive and negative trends. While maximum temperatures decrease in the central area of the country up to -6.9°C $(100\ \mathrm{yr})^{-1}$, they increase in Patagonia, up to 3.3°C $(100\ \mathrm{yr})^{-1}$. Figure 1 (bottom) presents the trends of the seasonal standard deviation, which represents the daily variability within a season. The standard deviation of the MinT presents significant (the confidence limits are the same as those of the means) negative trends in the majority of stations,

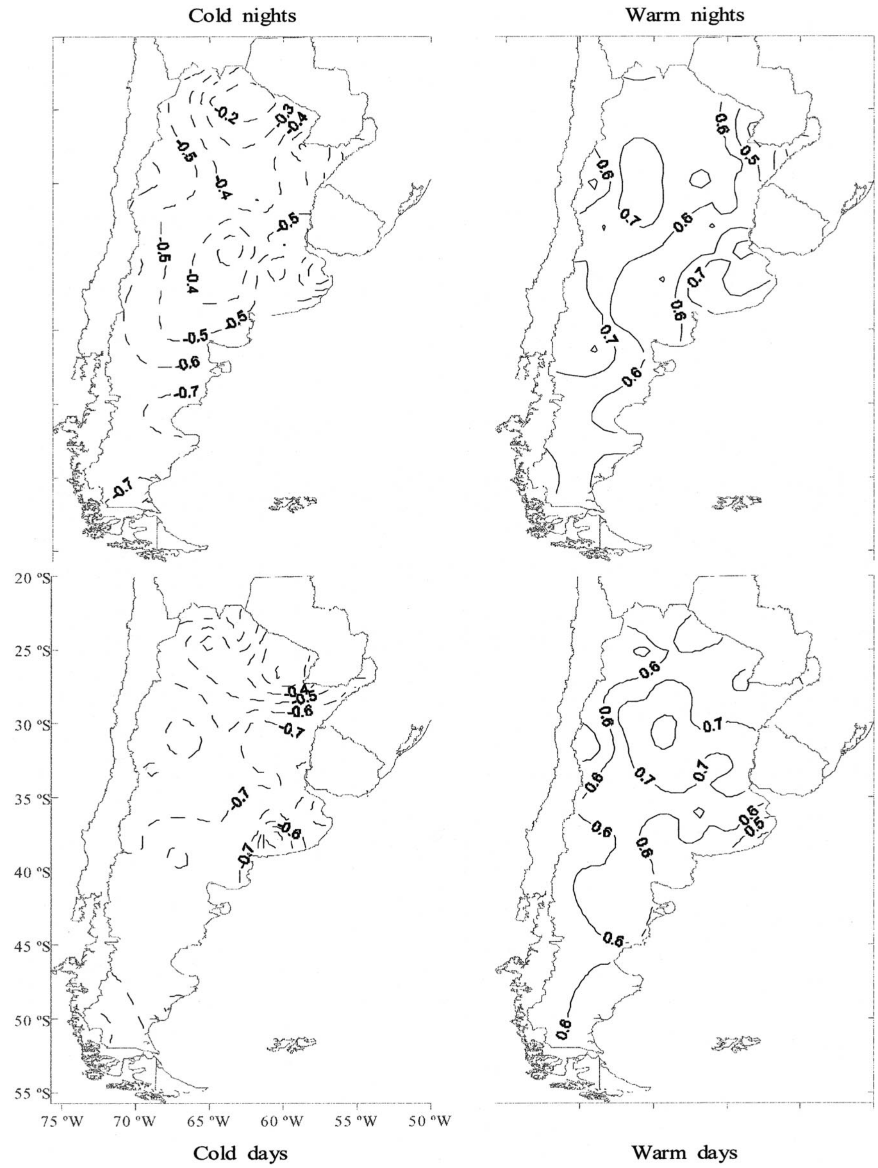

FIG. 5. Linear correlation between seasonal mean temperature and extremes in summer. Solid lines indicate positive values and dotted lines indicate negative values: (top left) number of cold nights, (top right) warm nights, (bottom left) cold days, and (bottom right) warm days. The values of $|r| < 0.31$ are generally not significant at the 5% confidence level.

with the largest values in the north of the country. There are numerous stations with significant negative trends in the standard deviation of MaxT in the central region (La Pampa). Therefore, the relationship between the mean and the variance in each of these two variables appears to be different.

In Fig. 2, the trends of the four summer extremes are shown. The number of cold nights per season clearly indicates a smaller number of occurrences per summer; similarly, the number of warm nights tends to increase, especially in the northeastern region. During the day, however, mainly in the center of the country, the cold days tend to increase and the warm days tend to diminish. The stations in Patagonia show once again the opposite pattern.

b. Trends in winter (JJA)

In winter, a slightly significant pattern can be seen (Fig. 3). MinT mean values also present positive (see Figs. 3a,b) and scattered negative significant trends. MaxT (Figs. 3c,d) presents the largest positive trends in Patagonia and is mainly negative in the northeast. The trends in the standard deviations, although significant in only a few cases, present different signs. Extreme trends were analyzed and no remarkable patterns

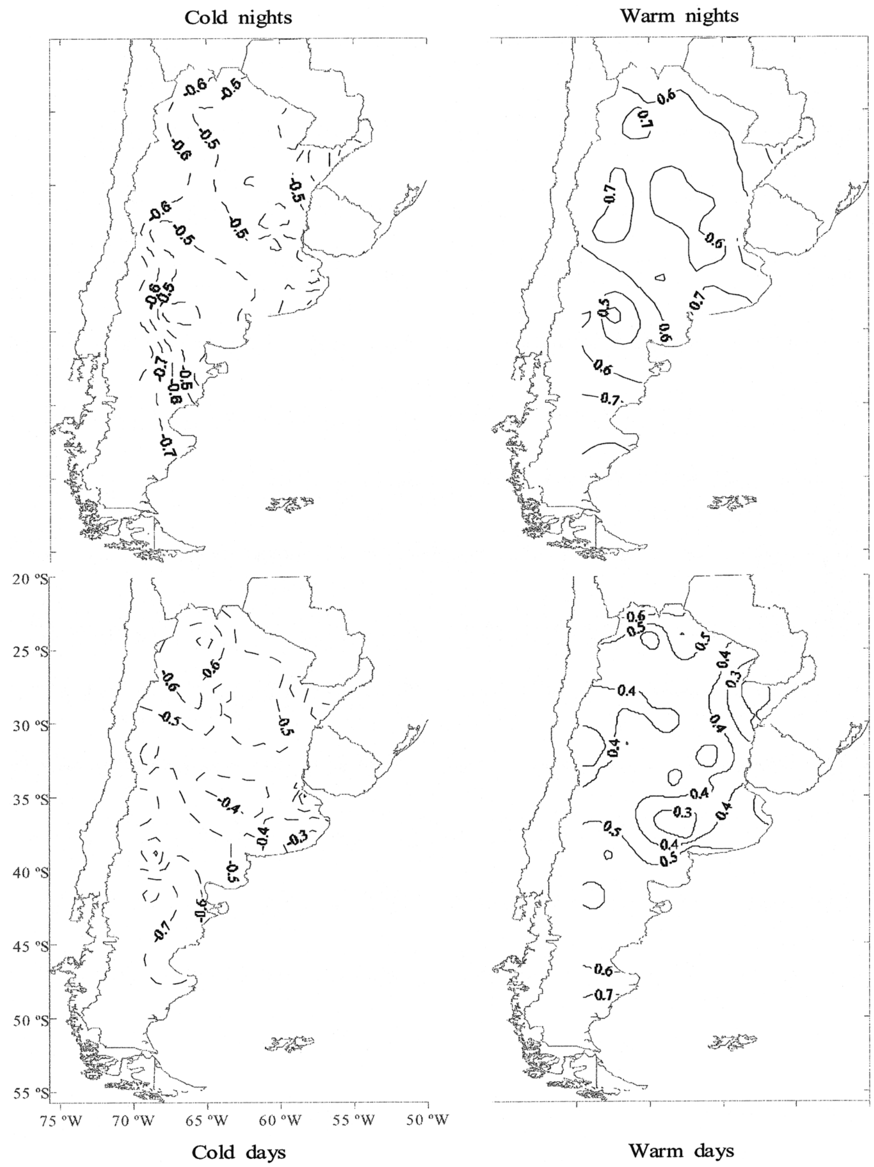

FIG. 6. Same as in Fig. 5, except for winter.

were detected. All stations in Patagonia have an increasing number (significant in some cases) of warm days and nights (results not shown).

c. Relationship between mean values and the occurrence of daily extremes

Regressions between the mean seasonal value and the number of extreme days (cold and warm nights and days) were performed in order to evaluate the relationship between the variability of both parameters as a whole. Figure 4 shows an example of the regression between seasonal mean temperatures and the number of extreme days in the season, for a station located at (27°45′S, 57°38′W). The different regressions show different slopes and, consequently, different R^2, as shown in each case. The extreme variable with a higher influence in the mean values in this case proves to be the number of cold nights, whereas the number of warm days bears no relation to the resulting mean value of seasonal temperature [e.g., a mean seasonal temperature value of approximately 16°C may occur within 0–10 (2 times the expected number) of warm days in the season].

The following figures show the correlation coefficients of these same regressions, calculated for all stations, where coefficients above (below) + (−) 0.31 are 5% significant if the time series is complete. In all cases, the sign of the correlation coefficient turns out to be as expected, that is, positive between the mean and the number of warm days or nights and negative the other way around. However, the large spatial variability, as well as the different behavior in the extremes variables, is remarkable.

Figure 5 shows that a change in the summer mean temperature has a large correlation with the occurrence of warm days and nights. However, there is virtually no linear relationship in stations located in the center and central northern region of the country to the occurrence of cold nights, even reaching nonsignificantly correlated values.

In general, in winter the relationship between the mean value and the extremes is smaller than that in the summer (Fig. 6). The largest correlations are found in the south (Patagonia) and in the case of warm nights. There are very low correlations between the occurrence of warm and cold days and the mean seasonal temperature in the east and northeast region of the country.

4. Summary and conclusions

Trends over 1959–98 of mean, standard deviation, and extreme (5th and 95th percentiles) maximum and minimum temperatures are analyzed. Conclusions of this exploratory study are based on local test decisions, as in many other studies mentioned above. It can be concluded that the variable that presents the largest number of stations with observed significant trends is the minimum temperature in summer, where positive trend values were found at many stations over 4°C (100 yr)$^{-1}$. The maximum temperature in summer presented strong negative values of the same magnitude in stations located in central Argentina. Both variables present more stations with strongest trends in summer.

The relationship between seasonal means and daily variability of temperature depends on the variable under review (maximum or minimum temperature), as well as on the season and location. In the case of minimum temperatures in summer, a large fraction of the area that yields most of the agricultural production of Argentina should result in reduced air temperature variability in the case of a warming climate, as is also shown by Robeson (2002) for the United States. At some stations in La Pampa, the maximum temperatures decrease both in their mean value and standard deviation in summer. In winter, an increase of mean value and standard deviation is generally observed, but most of the apparent trends were not statistically significant.

The standard deviation of the maximum temperature in winter is the variable that varies the least throughout the period studied, indicating that interdiurnal maximum temperatures in winter have not changed significantly. The largest changes were observed for all variables during summer.

In Patagonia, where Hoffmann et al. (1997) found the largest positive differences of decadal mean temperatures in the stations analyzed, high trends in extremes are shown. In general, the number of cold days and nights decreases while the number of warm days and nights increases in both seasons. In most other locations studied, the number of cold nights per summer has diminished. This is associated with the positive trends of mean minimum temperature and the decrease of the standard deviation.

The question, ‘‘What is the relationship between mean temperature values and daily extremes?’’ could be answered as follows.

1) In summer, there is a closer relationship between an increase in mean temperature and an increase in the occurrence of warm days and nights than between the mean seasonal temperature and a decrease of cold nights and days. Many stations in the north of the country show no significant correlation between the two variables.
2) In winter, the relationships between variables show little significance; the largest correlations between mean and extreme values are found in Patagonia. In the central region, where the largest agricultural and cattle production occurs, it cannot be inferred that an increase in maximum temperature would be related to an increased number of warm days in winter, although it is applicable in summer.

Analyzing only the changes in the mean is not enough to estimate the potential changes in the behavior of extreme variables in a scenario of warming climate. It is thus clear that a localized study per season and per variable is necessary and that the changes that occurred in mean and standard deviation are associated to different types of change in the occurrence of extremes. The application of the extreme value theory is recommended in future analysis.

Acknowledgments. The authors wish to thank the two anonymous reviewers for their very useful comments that improved this paper. This work was partially funded by Grants ANPCyT PICT 06921, UBA X135, and IAI CRN 055.

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