

Observed and Future Changes in the Temperature of the State of Jalisco, México Using Climdex and PRECIS

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Abstract

In the present study we analyzed the average and extreme temperatures observed and simulated by regional models in the State of Jalisco, Mexico. Data of daily mean, minimum and maximum temperatures of 208 stations distributed all over the State during the period 1971-2000 have been used to study the observed changes in the values of average and extreme temperatures. In addition, an assessment of future scenarios for the average and extreme temperatures associated with the increase in the concentration of greenhouse gases (GHG) was performed using simulations of a PRECIS (Providing Regional Climate for Impact Studies) regional climate modeling to create the climate for present (1971-2000), and future projections for the years 2020, 2050 and 2080. Observational analysis of the 208 stations suggests warming through increased intensity and frequency of hot events, with a decrease in the frequency of cold events. More than 35% to 76% of the stations have a tendency to a decrease in the number of cold events and 39% to 64% of the stations show a growing trend in the hot events. The percentage of stations showing warming through the indices of intensity of the highest maximums, lowest minimum temperatures is 37% to 70% and 30% to 65% of the stations, respectively. Observational analysis for the State of Jalisco as a whole also shows similar results. Anomalies in the average and extreme temperatures per month during the data period show an increase (decrease) in the frequency of hot (cold) events for every month. In general, PRECIS simulations under both scenarios A1B and A2 indicate an increase in warm events and decrease of cold extreme events towards the end of the 21st century. Both show similar patterns, but the scenario A2 shows slightly lower magnitudes of projected changes. Temperatures are likely to increase all year, but it is expected that changes in summer will be more prominent.

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Keywords

Average and Extreme Temperatures, Scenarios, Diurnal Temperature Range

1. Introduction

Since the industrial revolution, there has been a marked increase in the emission of greenhouse gases, mainly CO₂ and CH₄ in the atmosphere, raising atmospheric temperatures of the Earth's surface. The fourth assessment report of the Intergovernmental Panel on Climate Change [1] concluded that average surface temperatures have increased $0.74^{\circ}\text{C} \pm 0.18^{\circ}\text{C}$ following a linear trend in the past 100 years (1906-2005). The rate of warming in the past 50 years is nearly twice that in the past 100 years [1], largely attributed to anthropogenic influences. However the fifth assessment report of the Intergovernmental Panel on Climate Change [2] estimated a warming of $0.85^{\circ}\text{C} \pm 0.20^{\circ}\text{C}$, during the period 1880-2012, which has occurred independently verified using several sets of data. In the case of Mexico, the average, maximum and minimum temperatures have increased by about 0.2°C per decade during the period 1971-2003, for the country as a whole [3]. Regional studies on changes in temperature for China [4], Japan [5], Korean Peninsula [6], the Mediterranean region [7] [8], and Europe [9] show consistent patterns with a general warming. The last decade of the last century and the first of this century have been the warmest years ever recorded; the phenomenon has been global in nature, although warming trends do not show a great spatial and temporal variability.

Until recently, most of the studies on long-term global climate change through temperature records have focused on changes in mean values. The temperature is an integral component of climate variability and change on the regional scale. The extremes in temperatures are characterised by tolerance level exceeding daily temperature and their frequencies are of great interest in terms of human impact. They have important socio-economic implications, such as its direct impact on the performance of the farming, power generation and consumption, and the human health among other factors [10]-[13]. There are many regional studies on the basis of recorded data and only a few results of the model simulations.

In China, there has been a slight decline in 1 day of extreme maximum temperature during each season, except for the spring, but the extreme minimum temperature has shown a strong upward trend in each season [14]. In Northern and central Europe, there is an evidence of a decrease in the number of frosty days since 1930 [15], which appears to be associated with a sharp increase in minimum temperatures of winter. Symmetrical heating of warm and cold tails of the distribution of the daily minimum and maximum temperature during 1946-1999 has been evidenced in Europe [16]. It has been shown that for southern hemisphere countries such as Australia and New Zealand, the frequency of frozen days increased with the rise of the daily minimum temperature from 1961 [17]. Recent researches on the period 1960-2000 in indices of daily temperature over South America have indicated a significant trend towards increase in the percentage of warm nights and downward trends in the percentage of cold nights at many stations [18]. Many other regional studies have addressed the analysis of frequencies of warm and cold events and have indicated that the cold extremes are diminishing and the warm extremes are increasing [10] [19]-[23]. In the fifth report of the IPCC [2], it was concluded that changes in extreme temperatures are consistent with the observed warming of the climate.

More reliable regional climate change projections are now available for many regions of the world due to advances in modeling and understanding of the physical processes of the climate system. However, constraints arise due to uncertainties in factors such as change of population, economic variables, technological developments and other relevant characteristics of future human activity, which constitute important ingredients of climate simulation models. Therefore, certain carefully considered scenarios are developed to project global climate scenarios predicted for the future and their possible consequences. Houghton *et al.* [24] have concluded that the projections of the statistical aspects of weather phenomena and climate extremes can be derived from climate models that represent possible future climate states. The third assessment report (TAR) of the IPCC has incorporated future climate change and extreme weather events in these models [25]. Many studies have deduced that most of the increase in the global average observed during the second half of the 20th century, can be attributed to anthropogenic forcing [25]-[30]. Changes in the general warming and rainfall over the State of Jalisco indicate, using atmosphere-ocean-coupled general circulation models, an increase of the greenhouse effect

scenarios. There have been agreements made at global/regional scales to also determine the nature of the changes in the extremes in other regions of the world [22] [31]–[34]; however, a clear picture of such changes with regional details have not been made in this region of Mexico.

In this study an attempt is made to investigate current changes and projections to the end of the 21st century for the State of Jalisco, México, using temperature models.

2. Material and Methods

The data for average, maximum and minimum temperatures for the period 1971–2000 and 1981–2010 were obtained from the National Meteorological Service (SMN) belonging to the National Water Commission (CNA), attached to the Ministry of Environment and Natural Resources (SEMARNAT) of a network of 208 meteorological stations distributed in the State of Jalisco (**Figure 1**). Prior to the processing we carried out an assessment of the data quality as a prerequisite for the calculation of the indices, since any atypical or wrong value could have serious repercussions on the analysis of trends. Therefore, some basic procedures of data processing were performed to examine the data of the individual stations. This allowed the identification of some extreme outliers and also helped in the identification of possible inhomogeneity and lack of values in the data sets. Metadata files are configured for each station to identify doubtful values and track changes in the data sets. All suspicious daily temperature values were identified by the different quality controls; for example, the maximum temperature below the minimum temperature, daily values more than four standard deviations from the average for the time of year and also by visual inspection of the historical record. Suspicious records are identified using various data sources, and the erroneous values are replaced by the correct values. The stations used in the study are selected based on the quality of the data, the duration of data availability and homogeneity to comply with these requirements. Only 197 of the 208 analyzed stations were finally used [35] [36]. The simulations using

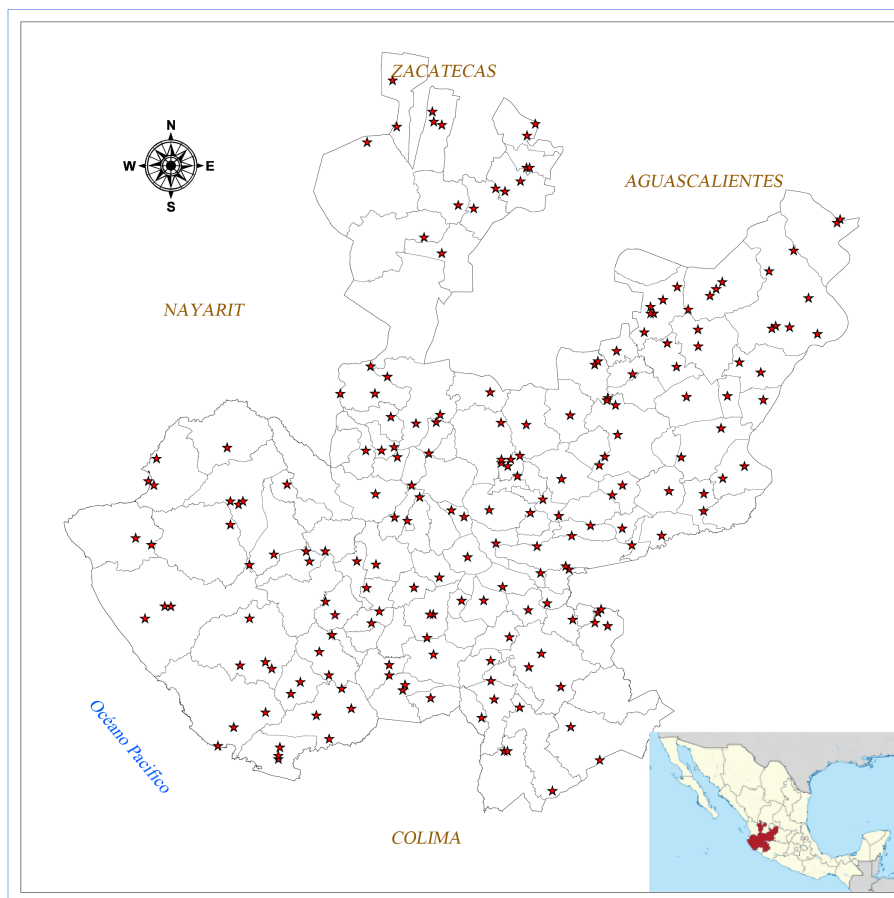


Figure 1. Geographical location of the 208 weather stations considered in this study.

PRECIS have been performed to generate the past climate (1971-2000) and for the future periods of 2020, 2050 and 2080 for two different socio-economic scenarios, both characterized by a focused regional development but with priority to economic issues in the first (scenario A2) and environmental issues in the second (scenario A1B). A detailed description of these scenarios is available in IPCC special report on emissions scenarios SRES, [37]. PRECIS is configured for a domain which extends from approximately $-101^{\circ}28'W$ to $-105^{\circ}42'W$ longitude and $18^{\circ}55'N$ to $22^{\circ}45'N$ latitude with $0.22^{\circ} \times 0.22^{\circ}$ of horizontal resolution. A complete description of PRECIS is provided by Jones *et al.* [38]. In this study, the characteristics of the mean and extreme temperatures are investigated to predict their future scenarios using data average, daily minimum and maximum temperatures of PRECIS for baseline (1961-1990) and the A1B and A2 scenarios 2020, 2050 and 2080.

An important issue that arises in assessing changes in extremes is how to objectively define and quantify the various types of extremes in the weather elements. The Commission of the World Meteorological Organization (WMO) for the team of experts in climatology concerning climate change detection, monitoring and indices (ET-CCDMI) has been coordinating efforts to develop a set of relevant indices and make possible their global analysis through regional participation. In this study, some of the indices developed by the ETCCDMI (**Table 1**) are calculated using RCLindex software at each station to assess trends and also evaluations were made using simulations with PRECIS during the same period.

The maximum and minimum temperature data from PRECIS using baseline (1971-2000) data are used to evaluate the ability of the model in the representation of the regional climatic characteristics of the temperature extremes on the basis of comparisons with *in-situ* observations for the State of Jalisco. To eliminate possible apparent biases due to the differences in density space between observation and model data representations, as well as the methodology, the data from the model have been downgraded in resolution to match it with the observation network. The daily mean, maximum and minimum temperatures from PRECIS data are extracted for the coordinates of each respective station for which real observational data are available. In addition, similar approaches in diagnostic analysis have been applied to both models, as well as the sets of observed data.

For the comprehensive analysis, the spatially aggregated monthly average indices for the State of Jalisco are calculated using the simple arithmetic mean of the respective indices of all stations analyzed to see changes in the annual cycle. Trends were calculated for each station and for the whole of Jalisco State on time series for all indices of average and extreme temperatures. Extreme indices usually do not follow a Gaussian distribution, and therefore a simple linear least-squares trend estimate would not be appropriate. Therefore, slope Mann-Kendall non-parametric estimators based on the statistical range are used to test the significance of the long-term trends

Table 1. List of extreme temperature indices used.

	Index	Description	Definition
Intensity Indices	TXx	Hottest day	Highest maximum temperature in a year
	TXn	Coldest day	Lowest maximum temperature in a year
	TNx	Hottest night	Highest minimum temperature in a year
	TNn	Coldest night	Lowest minimum temperature in a year
Frequency indices with percentile thresholds	TX90p	Hot days	Percentage of days in a year with maximum temperature above 90th percentile of daily maximum temperature distribution in the 1971-2000 baseline period
	TN90p	Hot nights	Percentage of days in a year with minimum temperature above 90th percentile of daily minimum temperature distribution in the 1971-2000 baseline period
	TX10p	Cold days	Percentage of days in a year with maximum temperature below 10th percentile of daily maximum temperature distribution in the 1971-2000 baseline period
	TN10p	Cold nights	Percentage of days in a year with minimum temperature below 10th percentile of daily minimum temperature distribution in the 1971-2000 baseline period
Range index	DTR	Diurnal temperature range	Annual mean of difference between maximum temperature and minimum temperature

in the time series [39]. These tests are widely used in environmental science, because they are simple and do not assume a distribution of residuals, to limit the effect of extreme values of the series, and they can cope with the missing values below detection limits.

3. Results and Discussion

Observational analysis in the whole State of Jalisco and the seasonal and annual mean surface air temperature of the region was carried out in the year 2015 by Ramírez *et al.* [3]. They showed an increase of 0.17°C over 60 years using the network of 197 stations, providing the first quantitative indications that the State of Jalisco shares aspects with large scale global warming. The decadal average temperatures trend analysis also provided a similar result. Although some studies have tried to perform an analysis of the climate change observed over the Western Mexico region, including the analysis of the extremes, there is still a lack of systematic and comprehensive analysis of the changes in the extremes. Therefore, we have attempted to analyze the extremes observed in the air surface temperature in terms of their intensity and frequency using daily data from the stations of the State of Jalisco.

Temperatures are well known to have large seasonal variations, which are also reflected in the annual cycles of extreme events of temperature [40]. It is of great interest to examine possible changes in annual cycles, to see if there is a detectable change in annual climatological patterns of occurrence of extreme events of temperature on the scale of the State of Jalisco. A simple way of determining if there have been notable changes in annual cycles is to examine the annual cycles of averages into two equal halves of the data period, using the semiaverage method of the estimation of change. To this end, the annual cycle in terms of all monthly average indices for both halves of the period consisting of 30 years each has been analyzed. Changes in the State of Jalisco refer to the comparison of indices over two periods, namely, 1971-2000 and 1981-2010, and these differences have been calculated for each month.

Indices of average monthly intensity of extreme events of temperature 1) the lowest minimum temperature of the year (TNn), 2) the highest minimum temperature of the year (TNx), 3) the lowest maximum temperature of the year (TXn) and 4) the highest maximum temperature of the year (TXx) in the two sub-periods are presented in **Table 2**. Changes in the averages between time periods give an idea of the intensity ($^{\circ}\text{C}$) incremental behavior. Annual cycles for both periods show very different patterns for each index of intensity (**Table 1**), which indicates that there are major changes in the basic characteristics of the seasonal cycle. However, incremental changes in both seasons show the temperature increasing yearly in almost all levels of intensity, in every month. But, the magnitudes of the rises in temperature vary from month to month and also vary from one index to another. The magnitudes of the changes are relatively less (0.40°C - 2.4°C) during the precipitation months (June-October), and the temperature rise is relatively high ($-0.40^{\circ}\text{C} \pm 3.47^{\circ}\text{C}$ to $-2.4^{\circ}\text{C} \pm 3.63^{\circ}\text{C}$) in the dry

Table 2. Intensity indices for monthly average extreme events of temperature for the State of Jalisco obtained through R-Climdex.

Changes	TNn the lowest minimum temperature of the year		TNx the highest minimum temperature of the year		TXn the lowest maximum temperature of the year		TXx the highest maximum temperature of the year	
	71 - 00	81 - 10	71 - 00	81 - 10	71 - 00	81 - 10	71 - 00	81 - 10
Positives	104	55	92	64	125	117	148	98
Negatives	128	98	144	89	108	36	86	55
Total	232	153	236	153	233	153	234	153
Average	-0.40	-0.87	-0.62	-0.19	0.25	2.40	0.65	1.23
Std. dev.	3.47	2.69	2.21	1.96	3.54	3.63	3.64	2.79
Max	14.80	5.86	5.00	4.00	11.00	12.31	9.00	7.31
Min	-13.00	-5.76	-8.00	-6.39	-10.00	-5.77	-28.00	-2.60
% Positives	44.83	35.95	38.98	41.83	53.65	76.47	63.25	64.05
% Negatives	55.17	64.05	61.02	58.17	46.35	23.53	36.75	35.95

period (November-May). In addition, changes in the temperature of the coldest day (TXn) are generally higher than for the other levels of intensity.

The differences in the annual cycles of the indices of frequency of events based on 10 and 90 percentile value of hot and cold threshold, namely 1) cold nights (TN10p), 2) hot nights (TN90p), 3) cold days (TX10p) and 4) hot days (TX90p), for both periods are presented in **Table 3**. Both the number of hot days and hot nights (TX90p and TN90p) show the frequencies increase in almost every month, while the cold days and cold nights (TX10p and TN10p) show a decrease in frequency in all the months of the year. In a similar trend to the intensity indices, the frequency indices also show relatively small changes during the months of the rainy season and relatively greater changes in the dry season. A statistical t-Student test has been used to determine the significance of the changes in the average. Changes in indices between the two periods are statistically significant except for the cold days, which show the same trend.

3.1. Trends at the Level of Stations

The Mann-Kendall trend estimates were calculated for indices of both temperature maximum and minimum in each of the 197 study stations and also to the spatially added regional time series for the State of Jalisco as a whole. All trend values were required to have a statistical significance at the 5% level. Trends of the extreme levels of the annual temperature of the stations are summarized in **Table 2** and **Table 3**. All levels of intensity of both hot and cold events (cold days and cold night-time temperatures; and hot days and hot night-time temperatures; TXn, TNN, TXx, TNN) showed a general upward trend. All the hot events (TX90p and TN90p) frequency indices also show a general increasing trend, and all levels of frequency of cold events (TX10p and TN10p) show a general downward trend. Many stations show changes towards warming by increasing trends of high maximum temperature (from 37% to 70%), less events of minimum temperature (from 35% to 76%), the number of hot days (from 47% to 79%) and hot nights (from 37% to 67%), while there is a decrease in the number of cold days (46% to 29%) and cold nights (from 64% to 33%) in the periods, 1971-2000 and 1981-2010, respectively. Opposite trends towards cooling are seen in some stations.

Many stations show changes towards warming. In this section, we examine their spatial characteristics. The spatial patterns of the trends in indices of intensity in the period 1970-2003 are presented in **Figure 2**. The highest maximum temperature (TXx) and the lowest minimum temperature (TNN) show increasing trends in large parts of the State. Trends in the rest of the intensity indices (lowest maximum temperature, TXn and highest minimum temperature, TNx) have less spatial coherence. However, most of the significant increasing trends are more to the North and to the West (coastal zone). The decreases of the observed trends in a few of the stations, are mostly insignificant for all levels of intensity.

General warming trends are seen from the frequency indices also. The frequency of cold events (TN10p and TX10p) show downward trends, while the frequency of hot events indicates a growing trend (TX90p and TN90p) (**Table 1** and **Table 2**). However, the decrease of the trends in the frequency of cold events (TX10p and TN10p)

Table 3. Frequency indices of warm and cold events to the 10 and 90 percentile value threshold for the State of Jalisco obtained through R-Climdex.

	TN10P cold nights		TN90P hot nights		TX10P cold days		TX90P hot days	
Changes	71 - 00	81 - 10	71 - 00	81 - 10	71 - 00	81 - 10	71 - 00	81 - 10
Positives	43	9	25	18	30	8	31	19
Negatives	24	18	42	9	34	19	34	8
Total	67	27	67	27	64	27	65	27
Average	4.40	2.13	-5.30	3.82	-3.02	-2.98	-0.75	7.01
Std. Dev.	14.39	12.67	15.66	7.71	14.68	9.50	20.60	12.59
Max	40.00	35.77	42.00	15.36	38.00	22.09	45.00	22.46
Min	-45.00	-7.40	-38.00	-9.07	-38.00	-24.60	-39.00	-12.17
% Positives	64.18	33.33	37.31	66.67	46.88	29.63	47.69	70.37
% Negatives	35.82	66.67	62.69	33.33	53.13	70.37	52.31	29.63

have large spatial extent throughout the State. Increasing trends in hot events (TX90p and TN90p) have less spatial coherence. Similar to the intensity indices, the majority of the most significant trends are to the North and West of the State.

It is important that any data of simulated models should be used only after a prior assessment of the ability and the reliability of the model based on comparisons with in-situ observations. Therefore, evaluation of the model is considered to be one of the most important steps in studies based on data from the simulated model. Regional high-resolution simulations generated using PRECIS have been studied in detail by Ramírez *et al.* [3] to determine the reliability of the model in the representation of the regional climatic characteristics. Simulations of air surface temperature in the State of Jalisco have been examined. However, the main objective of the evaluation was to examine PRECIS in its simulating of the climate in the State of Jalisco. Therefore, Ramírez *et al.* [3] have examined the evaluation of daily maximum and minimum temperature extremes in the State of Jalisco in detail and concluded that PRECIS is capable of capturing climate of State of Jalisco with an uncertainty of $\pm 1.7^{\circ}\text{C}$ (Figure 3 & Figure 4).

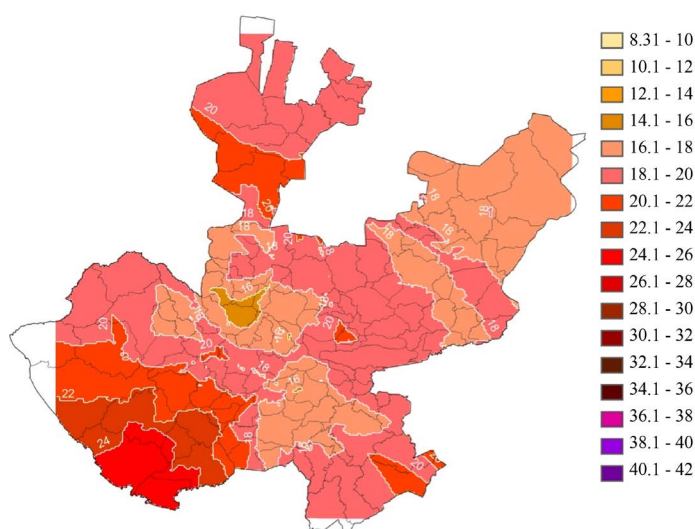


Figure 2. Spatial patterns of the trends in the indices of temperature intensity in the period 1970-2003 for the State of Jalisco.

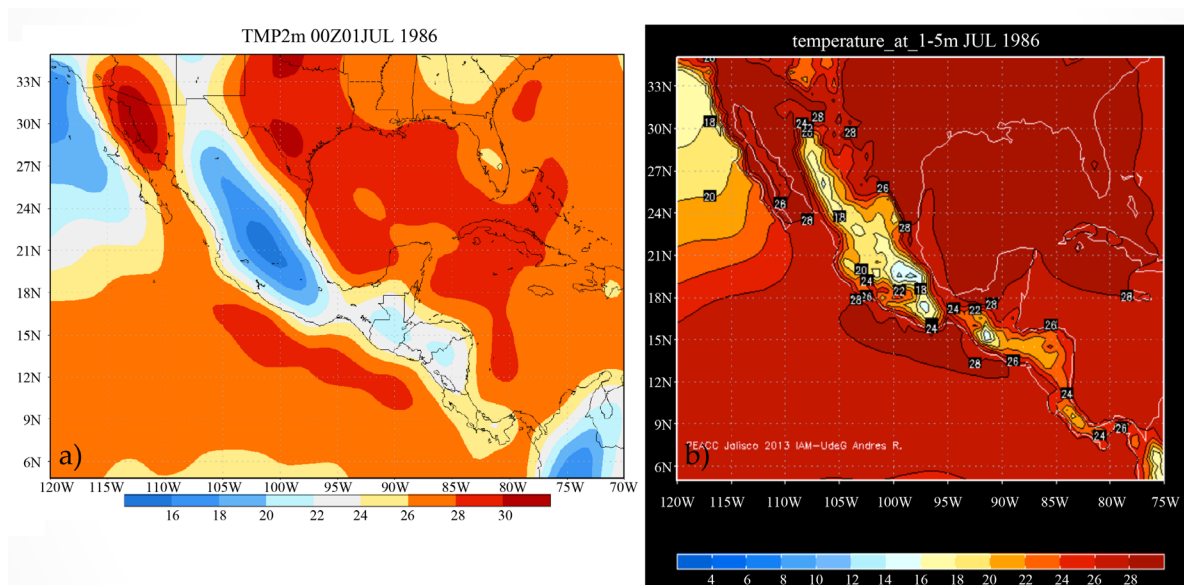


Figure 3. Temperature image for July 1986 of México obtained from (a) NOAA and (b) PRECIS database.

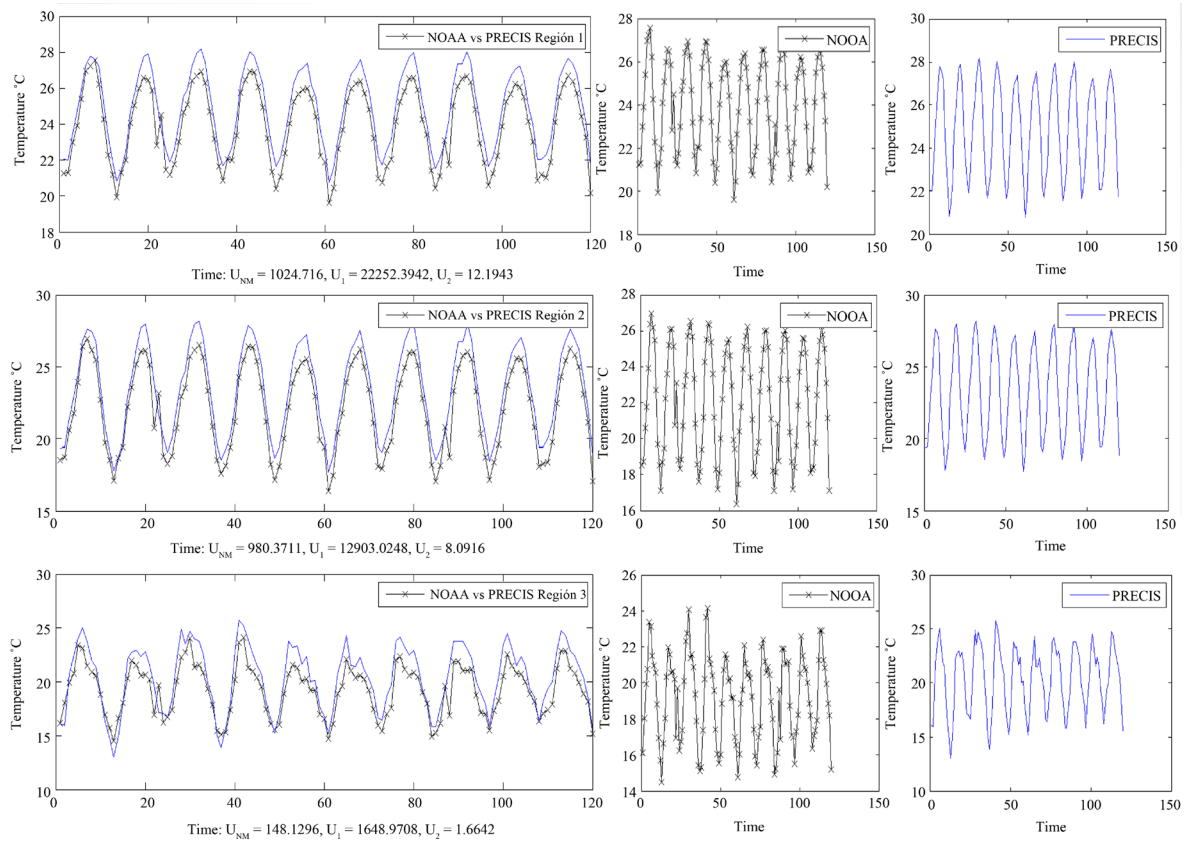


Figure 4. Comparison of temperatures for July 1986 of México obtained from (a) NOAA and (b) PRECIS database.

Ramírez *et al.* [3] have presented the annual cycle of average air surface temperatures and have shown that the highest temperature during the dry season, followed by the fall during the stormy and winter months, is well represented by PRECIS.

3.2. PRECIS Scenarios

Observational analysis suggests notable changes in temperature extremes over Jalisco. Therefore, it is of great interest to focus especially on the daily data to assess likely future changes towards the end of the 21st century. PRECIS-generated daily temperature data are used to predict changes in extreme temperatures in the periods 2020, 2050 and 2080. Ramírez *et al.* [3] have shown that PRECIS simulations in scenarios of increasing concentrations of greenhouse gases and sulfate aerosols indicate a marked increase in average air temperature in the State of Jalisco at the end of the 21st century. Their analysis also shows that the patterns of temperature change projected under A2 and A1B scenarios are similar, but the scenario A2 shows a lesser magnitude of projected change. Warming is monotonically predicted over the State of Jalisco (Figure 5).

The probability distribution function of the frequency of extreme events, using maximum and minimum daily temperatures observed from 197 stations, were calculated. From these probability distributions, the values of both tails on the extremes of the distribution of frequencies are selected so that 10% - 15% observations are kept outside chosen limits. These values are chosen to determine the frequencies of annual heating and cooling. Maximum temperatures of 15°C - 35°C are the values of the lower and upper tail, respectively. For the minimum temperatures, these values are obviously lower, and approximately 10°C and 25°C represents the values of the lower and upper tail.

Using these values as thresholds defined by the user, the frequency in terms of the number of days per year are calculated for the number of hot days, cold days, warm nights and cool nights on each baseline grid, for both A1B and A2 scenarios.

For the future scenarios (2020-2100), the frequencies of warm days ($T_x > 35^\circ\text{C}$) and nights ($T_n > 25^\circ\text{C}$) are

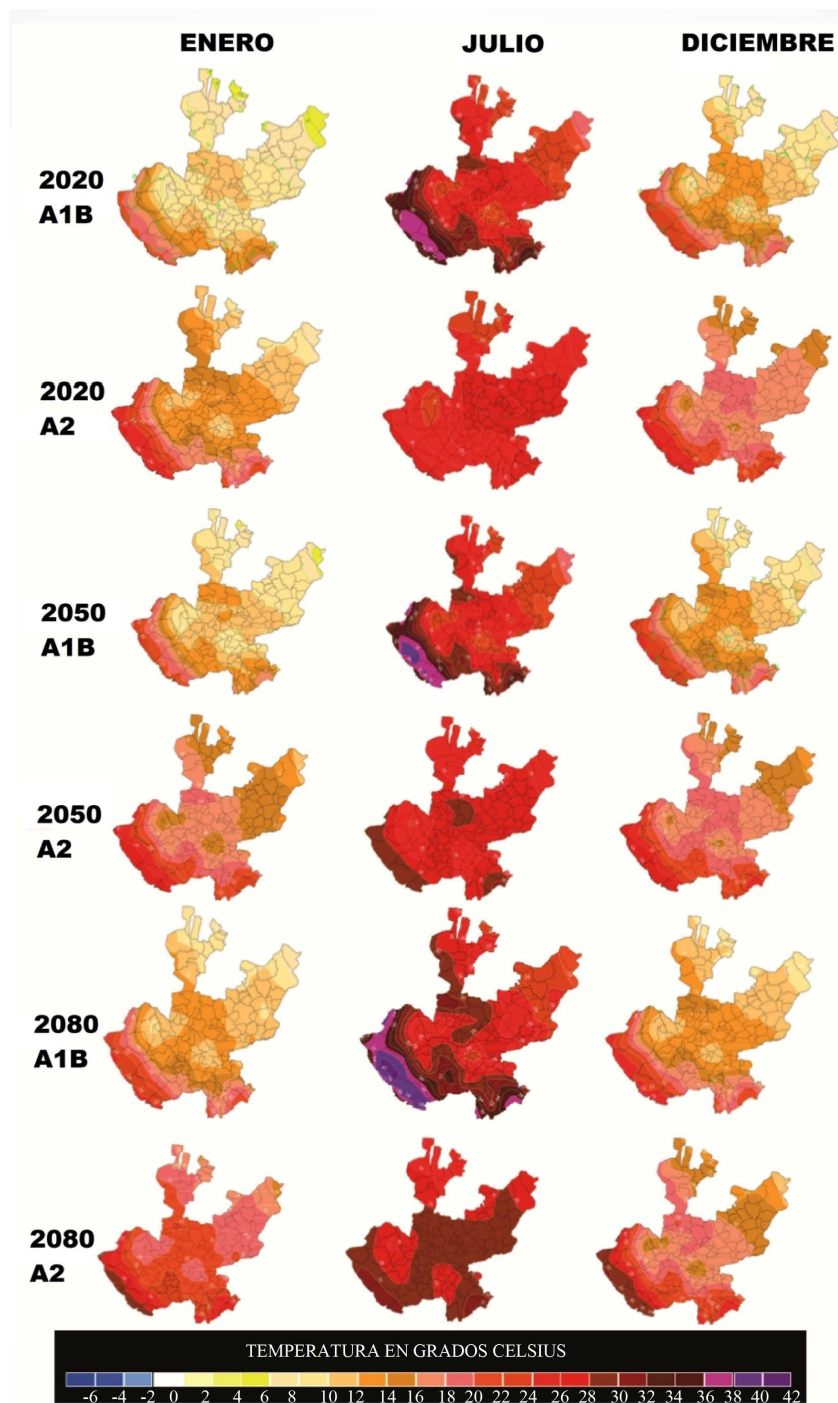


Figure 5. Projected temperature patterns of PRECIS under scenario A1B and A2 in the State of Jalisco.

increasing, while the frequencies of the cool days ($T_x < 15^\circ\text{C}$) and nights ($T_n < 10^\circ\text{C}$) are declining.

The increase in the warm nights of A2 scenarios with respect to the baseline is 180%, which is the highest in terms of percentage days, while the frequency of cold days shows a lesser decreasing index of 35%. Higher indices are seen in the frequencies related to minimum temperatures than frequencies related to the maximum temperature.

Greater changes are seen through both warm and cold frequencies in the A2 scenarios compared with the A1B

scenarios. The regression method has been used to correct the bias using indices calculated with the model and the observed data. Correction of bias estimates also show similar results with slightly lower magnitude. Therefore, similar to the observed results, the rate of increase of hot events and decrease of cold events is more notable at night, *i.e.*, minimum extreme temperatures.

Diurnal temperature range (DTR). In the northern hemisphere, it is expected that surface air temperatures rise steadily from January to June and decrease from July to December of each year. In the State of Jalisco, the basic character of the annual cycle of surface temperature follows this behavior. The rainy season is active throughout the region during the months of July to mid-September. Therefore, higher temperatures are experienced usually from April to June, immediately before the storms, and high rainfall is experienced from July to September. Annual cycles in terms of monthly variation for the average of maximum/minimum temperatures and extreme indices of highest maximum temperature and lowest minimum temperature show increase in maximum temperature from March, reaching a value peak in June and gradually decreasing towards December.

The stormy months, due to clouds and a humid climate, show a reduction of the maximum temperatures and increase in minimum temperatures [40] [41]. The annual cycle of the diurnal temperature range (DTR), which is defined as the difference between daily maximum and minimum temperatures, is affected by variation in the annual cycle of maximum and minimum temperature. The minimum temperature is controlled to a large extent by a decrease in long-wave radiation, while the maximum temperature is strongly affected by solar heating of the surface and partially by the sensible and latent heat [42]-[44]. Trends in DTR can be affected by a large scale increase in GHGs and aerosol [45] [46].

The DTR was calculated for the baselines 1971-2000 and 1981-2010, as well as scenarios A1B and A2 (2071-2100). In **Table 4**, the monthly average values mean DTR for the State of Jalisco for each time interval are shown. The basic characteristics of temperature variation are well reflected with high values of DTR's of 66% and 71% increase. The annual cycles of DTR in A1B and A2 scenarios also show similar patterns. However, reduced DTR values contribute 33 and 29 percent of the sample respectively for the studied periods.

4. Conclusions

A comprehensive analysis has been carried out in the present study of extreme temperatures observed in the State of Jalisco, using daily representative data of good quality to detect and quantify the climate changes observed in terms of extremes and also to assess the representations of the climate obtained from regional climate models and provide probable future extreme temperature projections based on their simulations of two different socio-economic scenarios (A1B, and A2). Changes in extremes are studied in terms of their frequency, intensity and duration using a standard set of indices defined objectively in a globally standardized framework. The followings are some of the main conclusions based on the results presented in various sections of this document.

Observational analysis based on the daily maximum and minimum temperature for the period 1971-2000 and 1981-2010 using a network of 208 well distributed stations indicated a general warming in the State of Jalisco, both through indices of frequency and of intensity of extreme temperatures. Changes in semiaverages in the annual cycles in terms of extreme monthly temperatures show a warming in every single month. Spatial patterns

Table 4. DTR of the stations in the State of Jalisco in the periods 1971-2000 and 1981-2010.

Changes	DTR	
	1971-2000	1981-2010
Positives	155	109
Negatives	79	44
Total	234	153
Average	1.26	1.27
Standard Deviation	3.29	2.87
Maximum	15	11.02
Minimum	-10	-13.42
% Increment	66.24	71.24
% Diminution	33.76	28.76

indicate marked changes to warming across the State. The highest magnitude changes in extreme temperatures are seen in the spring and summer months more so than in the rest of the year.

The study also presents future scenarios of likely extreme temperatures in the State of Jalisco, deduced from a regional climate modeling system known as PRECIS, for the period 2020-2080. Simulation models suggest a reasonable ability in the representation of the present climate of Jalisco. Simulation models with scenarios of increased concentration of greenhouse gases and sulfate aerosols indicate a marked increase in both temperature maximums and minimums towards the end of the 21st century. Space-time graphics from PRECIS of the daily maximum and minimum temperatures show general projections of a warming of around 3.5°C over the whole year towards the end of the 21st century, but the changes in the dry season are more prominent than those in the rest of the year.

PRECIS under both the A2 and A1B scenarios indicates frequency of episodes of extreme heat and also the consequent increase in intensity towards the end of the 21st century. There is a marked decrease in the frequency of cold events obtained by the maximum temperatures, as well as the minimum. Both scenarios A1B and A2 show similar patterns of projected changes in extreme temperatures towards the end of the 21st century. However, the scenario A2 shows lower magnitudes of the projected changes than the scenarios A1B.

So, while the analysis of the observed trends and future projections of the extremes in surface temperature indicate large-scale regional changes through all indices, it is necessary to examine the extremes in detail, both on spatial and temporal scales and also to study the factors affecting the improvement of the extremes. Future scenarios are based on assumptions about the future development of the world. Climate models do not reproduce the weather precisely in a specific place at a specific time. The estimates have uncertainties associated with them, which should be evaluated using more sets of model simulations. Changes in the duration of insolation, wind speed and relative humidity are also important to study future climate change with all the possible intermediate scenarios.

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