Time Series Analysis of Climatic Variables in Peninsular Spain. Trends and Forecasting Models for Data between 20th and 21st Centuries

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Abstract: Time series of mean monthly temperature and total monthly precipitation are two of the climatic variables most easily obtained from weather station records. There are many studies analyzing historical series of these variables, particularly in the Spanish territory. In this study, the series of these two variables in 47 stations of the provincial capitals of mainland Spain were analyzed. The series cover time periods from the 1940s to 2013; the studies reviewed in mainland Spain go up to 2008. ARIMA models were used to represent their variation. In the preliminary phase of description and identification of the model, a study to detect possible trends in the series was carried out in an isolated manner. Significant trends were found in 15 of the temperature series, and there were trends in precipitation in only five of them. The results obtained for the trends are discussed with reference to those of other, more detailed studies in the different regions, confirming whether the same trend was maintained over time. With the ARIMA models obtained, 12-month predictions were made by measuring errors with the observed data. More than 50% of the series of both were modeled. Predictions with these models could be useful in different aspects of seasonal job planning, such as wildfires, pests and diseases, and agricultural crops.

Keywords: time series; climate change; ARIMA; peninsular Spain

1. Introduction

Among the most influential climatic elements in the biosphere and human activities are surface air temperature and precipitation. For this reason, much attention has been focused on their measurement. The first attempt to obtain the mean global surface air temperature time series was made at the end of the 19th century by Köppen in 1883 [1]. His series covered a long period of time, 1731–1871 [1].

Subsequently, there have been several studies using the time series of monthly temperature records, as noted by Jones et al. [2].For example, in [2] there are references to Willet, who in 1950, analyzed the temperature trend of the southern hemisphere with a temperature record from 1880 to 1940; Mitchell, who in 1961, analyzed data from 47 stations with a record of southern hemisphere temperatures from 1880 to 1957; Damon and Kunen, who in 1976, examined the temperature records of 57 stations from 1943 to 1974; Van Loon and Williams, who in 1977, analyzed the total annual data of the Antarctic station from 1956 to 1973. In addition, Hansen and Lebedeff [3] analyzed surface air temperature data using a time series with records from 1880 to 1985, checking the significance of the trends using an artificial global temperature history generated by a three-dimensional general circulation model. Regarding time series related to precipitation, Vinnikov et al. [1] point out that the first works on a possible trend of precipitation were made by Aposava and Gruza in 1982, Bradley et al. in 1987, and Diaz et al. in 1989. Therefore, the detection of

trends in climatological data has become central to the discussion of climate change due to the enhanced greenhouse effect [4]. Indeed, the central task of climate change detection studies is to determine whether an observed change or trend is "significant" [5]. Several studies focused on global temperature trend analysis. Seater [6] conducted a study on the trends of the terrestrial temperature with annual time series from 1854 to 1989 for the globe as a whole as well as for the north and south hemisphere separately. Harvey and Mills [7] analyzed annual temperatures of the northern and southern hemisphere from 1856 to 1998 based on the study of linear trends.

Interest in predicting the climate trend is shown in [8], which presents a system to generate time series of global surface temperature to observe its trend, while also reviewing methods of statistical trend estimation methods in climate data. Focusing on studies of specific regions, at the European level, there are several studies: Schönwiese and Rapp [9] analyzed the trend of European temperatures from 1891 to 1990. Klein Tank et al. [10] analyzed the trends of European daily temperatures. Moberg et al. [11] analyzed European temperatures from 1901 to 2000. Regarding peninsular Spain, there are also several studies: among others, Brunet et al. [12] developed a database called Spanish Daily Adjusted Temperature Series (SDATS), composed of the 22 longest series of mean daily temperatures (Tmed), mean daily maximum temperatures (Tmax), and mean daily minimum temperatures (Tmin), which covered the period of 1850–2005. Prieto et al. [13] analyzed data from 45 stations distributed in peninsular Spain in the 1955–1998 period, and they detected a generalized decreasing trend in the annual frequency of extreme events for most of the studied observatories due to a non-linear shift in the annual mean minimum temperatures associated with a generalized warming in the area. In Spain, the masses of maritime arctic, continental and maritime polar, and maritime and continental tropical air predominate [14].

In terms of precipitation, globally, several studies have been carried out, including that of Westra et al. [15] on globally increasing trends in the annual maximum daily precipitation obtained from a global dataset of 8326 stations between 1900 and 2009. Lau et al. [16] conducted a study on the characteristics of precipitation on the global scale in the context of global warming. Ren et al. [17] analyzed the global precipitation trends over the period of 1900–2005. Bin Wang et al. [18] carried out a study on decadal trends of global precipitation.

At the European level, Klein Tank et al. [19] studied the precipitation trends of more than 100 meteorological stations in Europe in the period from 1946 to 1999. These authors also conducted a study on a set of daily precipitation data for the 20th century [20]. Kivinen et al. [21] studied precipitation trends from of nine meteorological stations located in Finland, Norway, Sweden, and Russia in the 1914–2013 period.

Regarding the study of precipitation in peninsular Spain, its complex topography and great variability of precipitation make it a particularly interesting region for the study of this variable, as its topography contributes to the spatial distribution of precipitation regimes [22]. Studies in this area on the identification of patterns and trends of precipitation can be found in [23–28] among others.

In contrast, there are a limited number of studies with a focus on the analysis of historical series of observed data in order to obtain models that represent the characteristics of the variations and allow short-term prediction. Thus, prediction models can serve to help with local needs (such as the planning of interventions for agricultural or forest pests, forest fires, rural buildings, and agricultural crops) [29]. This is the case for the use of ARIMA models [26]. In Spain, the use of these models is applied to a case of series of two provincial capitals Madrid and Barcelona [26] and to the case of the eight capitals of Andalusia [30] for monthly precipitations and temperatures. The aim of this work is to analyze and represent trends using simple ARIMA models [26] since the studies on mainland Spain go up to 2008 [31]. The variation in time series of mean monthly temperature is measured in degrees Celsius, and total monthly precipitation is measured in millimeters for the 47 provinces of peninsular Spain, while allowing future observations to be predicted in the short term. The description and identification phase of the model were used to analyze each possible trend with the classic linear regression method, considering

those that presented a slope statistically different from zero to be significant. However, this method requires independence and normality of the residuals [8]. ARIMA models have the advantage of collecting the variation components of the analyzed series (trend, seasonality, and random noise), and the analysis of time series of climate data can be a valuable tool in investigating patterns of variability and, perhaps, even in predicting short- and long-term changes in the series [32]. Many time series forecasting methods are based on the analysis of historical data. They assume that past patterns in the data can be used to forecast future events. In recent years, one of the most popular methods of time series modelling is ARIMA modelling. Its main aim is to carefully and rigorously study the past observations of a time series to develop an appropriate model that can predict future values of the series [33].

2. Materials and Methods

In this study, the data come from the State Meteorological Agency (AEMET) stations in each of the provincial capitals. The variables used are mean monthly temperature (in °C) and total precipitation (in mm) for the month.

2.1. Study Area and General Climate Characteristics

Figure 1 presents the situation of each of the stations considered, one in each provincial capital (black points). In total, 47 temperature series and 47 precipitation series were analyzed, although the number of data in each ranges between 300 and 888.

Figure 1. Location of stations in provincial capitals of mainland Spain.

Table 1 shows the information of the stations of the AEMET in peninsular province capitals. The first column shows the autonomous community to which each station belongs; the second column is the name of the city where the data collection station is located; the third column is the identified period of years for which data are available for both variables; the fourth column shows the number of data items for each series (*n*) together with the number of years comprising the period (number of years); the last three columns correspond to the geographic information (altitude, latitude, and longitude) that was used to obtain maps (Figure 1).

Table 1. Information of the stations of the AEMET in provincial capitals, sample size, and period of data availability in this study for both variables.

Autonomy Community	Station	Period	Data Sample (*n*/num. years)	Altitude (m)	Latitude	Longitude
	Zaragoza	1983–2013	372/30	225	41°43′30″ N	00°48′39″ W
Aragón	Huesca	1983–2013	372/30	390	42°01′50″ N	00°35′05″ W
	Teruel	1983–2013	372/30	1043	40°32′30″ N	01°01′53″ W
Asturias	Oviedo	1972–2013	504/41	336	43°21′12″ N	05°52′27″ W
Cantabria	Santander	1954–2013	720/59	5	43°25′45″ N	03°49′53″ W
La Rioja	Logroño	1983–2013	372/30	353	42°27′08″ N	02°19′52″ W
Navarra	Pamplona	1954–2013	720/59	450	42°49′04″ N	01°38′18″ W
	Vizcaya	1983–2013	372/30	29	43°17′26″ N	02°52′24″ W
Basque Country	Gipuzkoa	1983–2013	372/30	251	43°18′23″ N	02°02′28″ W
	Álava	1983–2013	372/30	563	42°53′20″ N	02°40′22″ W
	A Coruña	1961–2013	636/52	58	43°21′57″ N	08°25′17″ W
Galicia	Pontevedra	1963–2013	600/50	108	42°26′18″ N	08°36′57″ W
	Ourense	1949–2013	780/64	400	42°25′10″ N	08°05′12″ W
	Lugo	1985–2013	348/28	445	43°06′41″ N	07°27′27″ W
	Valladolid	1951–2013	756/62	735	41°38′27″ N	04°45′16″ W
	Ávila	1983–2013	372/30	1130	40°39′33″ N	04°40′48″ W
	Salamanca	1983–2013	372/30	775	40°57′27″ N	05°39′44″ W
	Palencia	1984–2013	360/29	874	41°59′44″ N	04°36′10″ W
Castile and León	Segovia	1989–2013	300/24	1005	40°56′43″ N	04°07′35″ W
	Zamora	1983–2013	372/30	802	41°13′55″ N	05°29′52″ W
	Burgos	1983–2013	372/30	1001	42°19′20″ N	03°27′32″ W
	Soria	1983–2013	372/30	1082	41°46′30″ N	02°28′59″ W
	León	1983–2013	372/30	916	42°35′18″ N	05°39′04″ W
	Albacete	1967–2013	564/46	702	38°57′06″ N	01°51′45″ W
	Ciudad real	1971–2013	516/42	628	38°59′21″ N	03°55′13″ W
Castilla–La Mancha	Guadalajara	1949–2013	780/64	639	40°39′33″ N	03°10′24″ W
	Toledo	1975–2013	468/38	478	39°56′35″ N	03°54′57″ W
	Cuenca	1983–2013	372/30	900	40°04′30″ N	02°12′17″ W
Extremadura	Badajoz	1983–2013	372/30	185	38°53′00″ N	06°48′50″ W
	Cáceres	1983–2013	372/30	362	39°47′20″ N	06°23′37″ W
Madrid	Madrid	1983–2013	372/30	609	40°28′00″ N	03°33′20″ W
	Tarragona	1984–2013	360/29	53	41°06′42″ N	01°08′42″ E
Cataluña	Girona	1974–2013	480/39	143	41°54′42″ N	02°45′48″ E
	Lleida	1972–2013	504/41	217	41°36′32″ N	00°41′43″ E
	Barcelona	1968–2013	552/45	4	41°17′34″ N	02°04′12″ E
	Valencia	1983–2013	372/30	69	39°29′07″ N	00°28′28″ W
País Valenciano	Alicante	1968–2013	552/45	43	38°16′58″ N	00°34′15″ W
	Castellón	1976–2013	456/37	43	39°57′26″ N	00°04′19″ W
Murcia	Murcia	1983–2013	372/30	57	37°59′28″ N	01°07′42″ W
	Jaén	1989–2013	300/24	580	37°46′39″ N	03°48′32″ W
	Sevilla	1962–2013	624/51	34	37°25′00″ N	05°52′45″ W
	Granada	1940–2013	888/73	690	37°08′10″ N	03°38′00″ W
Andalucía	Málaga	1951–2013	756/62	500	36°46′42″ N	04°23′03″ W
	Almería	1968–2013	552/45	21	36°50′47″ N	02°21′25″ W
	Córdoba	1986–2013	336/27	90	37°50′39″ N	04°50′46″ W
	Cádiz	1983–2013	372/30	2	36°29′59″ N	06°15′28″ W
	Huelva	1983–2013	372/30	51	37°16′29″ N	06°50′17″ W

The climate of peninsular Spain is mainly divided into 3 types: oceanic, continental, and Mediterranean. Atlantic Spain (with an oceanic climate) extends from Galicia to the Pyrenees (Table 1—Galicia, Asturias, Cantabria, La Rioja, Navarra, and País Vasco). The Mediterranean inland climate extends mainly through the Central Plateau (Table 1—Castile and León, Castilla–La Mancha, and Extremadura). Its climate is Mediterranean but with continental characteristics due to the peninsular orography. The Mediterranean Coastal climate extends over the whole Mediterranean coast of Spain (Table 1—Cataluña, Comunidad Valenciana, and Murcia). The Andalusia region has all three characteristics: the Atlantic influence in its Atlantic coastal provinces (Huelva and Cádiz, oceanic climate), the Mediterranean with continental characteristics (Sevilla, Córdoba, and Jaén), and the Mediterranean (Granada, Málaga, and Almería) [34]. For the purposes of this study, 4 zones were considered taking into account the mentioned climate characteristics.

The first area is the north of peninsular Spain (**zone I**: Zaragoza, Huesca, Teruel, Oviedo, Santander, Logroño, Pamplona, Vizcaya, Gipuzkoa, Álava, A Coruña, Pontevedra, Ourense and Lugo);the second zone is the north and south plateau and the central system (**zone II**: Valladolid, Ávila, Salamanca, Palencia, Segovia, Zamora, Burgos, Soria, León, Albacete, Ciudad real, Guadalajara, Toledo, Cuenca, Badajoz, Cáceres, and Madrid);the third zone is the Mediterranean strip (**zone III**: Tarragona, Girona, Lleida, Barcelona, Valencia, Alicante, Castellón, and Murcia); and the fourth is the temperate Mediterranean zone (**zone IV**: Jaén, Sevilla, Granada, Málaga, Almería, Córdoba, Cádiz, and Huelva).

2.2. Statistical Analyses

Climate data analysis requires a study of homogeneity [35,36]. The climatic time series are influenced by inhomogeneities, i.e., non-climatic factors, such as changes in observational instruments, station relocations, and changes in station environment. A homogenous time series is defined as one where variations are caused only by variations in climate. Time series influenced by inhomogeneities may lead to deceptive conclusions regarding the state of climate and possible trends included [21]. In this study, we applied the tests of SNHT [37] to detect inhomogeneities in time series of temperature and precipitation. This was performed using Excel Statistics. The normality of climatic series was studied using the test of Lilliefors [38].

In order to detect the trend, an analytical adjustment by regression was made. In the description stage of the series, with the graphs of temperatures and precipitations time series, linear regression models were adjusted as a function of time, confirming the significance (+ or −) of coefficient b representing the slope of the straight line [39], and we completed the study using a Mann–Kendall trend test [40,41]. The magnitude of the trend with 95% confidence intervals was calculated using Sen's slope [42].

The application of the Box–Jenkins methodology [43] requires values measured at regular intervals of time; therefore, we proceeded to complete missing data in each series considering that there was a low percentage (less than 1%) of missing data in the series analyzed. To complete each series, simple interpolation methods were used, as they are usually isolated values. In this case, the missing value in time t was completed with the mean of contiguous data (at times t − 1 and t + 1), or in case of any missing contiguous data, the average of the month was used [44]. This method was chosen after reviewing, checking, and comparing other methods in some stations and proving that the values obtained were not notably different from those obtained with the simple average method or regression methods [44]. Then, an exploratory analysis of data series was performed (outlier's detection and lack of stationarity in means and variances).

The analysis of the series was carried out using ARIMA models based on stochastic process theory; obtaining the model assumes the existence of linear dependence between the variables whose values constitute the observed series [45]. The methodology used in this study for obtaining these models was established by [43]. With the complete and homogeneous series, the evolution graphs of the data as a function of time allow one to observe trends and possible periodicities, such as seasonality or variations in the dispersion. In relation to the analysis of trends, the word "trend" refers to a highly significant linear change (i.e., a level of confidence greater than 95%) in the value of some variable [46].

Given that these methods do not model well the trend in the case of lack of independence between the data, as occurs in the data of climatic series, the models based on stochastic processes, such as the ARIMA, adequately collect these dependencies due to the trend and seasonality. Thus, these variations were verified with the graphs of the simple autocorrelation function (ACF). In the case of trend, it was eliminated by taking differences of the type $x_t - x_{t-1}$ and, in case of seasonality, it was eliminated by taking differences of the type $x_t - x_{t-12}$ to obtain a stationary series. From the simple and partial autocorrelation functions (PAF) of the stationary series, it is possible to identify possible models that can represent the evolution of the observed data.

Given that the studied variables present seasonality, as they are monthly series of temperature and precipitation, the models to be estimated are of the SARIMA type (seasonal autoregressive integrated moving average), whose general representation is [43]:

$$ARIMA\ (p,d,q) \times (P, D, Q)_s$$

where *p* is the number of AR parameters; *q* the number of MA parameters of the regular or non-seasonal part of the series; *d* is the number of non-seasonal differences, usually of the type $x_t - x_{t-1}$; *P* is the number of AR parameters of the seasonal part (SAR); *Q* is the number of MA parameters of the seasonal part (SMA);p and *D* is the number of differences with seasonal period *s* (in this case *s* = 12), usually $x_t - x_{t-12}$.

The estimation of the parameters of the model was made by optimization algorithms. Once the model was adjusted, the significance of the estimated coefficients was checked, and compliance with the hypotheses for these models was verified through the analysis of residues (randomness of the Box–Pierce test [47] and heteroscedasticity by test F for constant variance, comparing the 1st and 2nd half of the series). If the residues comply with the model hypothesis ($p > 0.001$), 12-month predictions are made that are compared with observed values of the 12 months of the year following the last of the series used to obtain the model. The average of those 12 errors will be close to zero.

The statistical software used was Excel Statistics, STATGRAPHICS Centurion XVII.I., Software R.

3. Results

3.1. Homogeneity Tests

The SNHT homogeneity test allowed us to consider homogeneous data series ($p > 0.01$) except in Cantabria ($p > 0.007$), A Coruña ($p > 0.001$) Ourense, and Malaga ($p < 0.0001$). The time series for both temperature and precipitation did not give a normal distribution.

3.2. Trend Analysis

To obtain an ARIMA model, in the first stage, the graph of the data is observed as a function of time with the option of making a linear adjustment of the trend. The results of this option showed that in temperatures it is significant ($p \leq 0,05$) in the series of Oviedo, Santander, A Coruña, Ourense, Valladolid, Salamanca, Albacete, Ciudad Real, Toledo, Girona, Barcelona, Castellón, Sevilla, Málaga, and Almería, with the magnitude varying between 0.0022 and 0.0074. That is, there were 15 series of temperatures with a significant, positive trend out of a total of 47. In precipitations, the trend was significant ($p \leq 0.05$) for the case of Santander, Ourense, and Zamora (negative) with magnitudes of −0.041, −0.047 and −0.042, respectively, and Burgos and Jaén (positive) with magnitudes of 0.042 and 0.064, respectively (See Table 2). This trend must be considered orientative and deterministic. Therefore, with the non-parametric methods of Mann–Kendall and Sen's slope (See Table 3), it was compared with that obtained with the linear trend, and the results of positive trends in temperatures in the same weather stations coincide. Similarly, the positive precipitation trends in Burgos and Jaén and the negative precipitation trend in Santander, Ourense, and Zamora coincide.

Table 2. Summary of results of the trend analysis for the temperature and precipitation series.

Province	Temperature Trend	Temperature Coefficient	Temperature *p*-Value	Precipitation Trend	Precipitation Coefficient	Precipitation *p*-Value
Oviedo	T = 11.6 + 0.0027t	0.0027	0.0246	N.S. (−)	−0.0005	0.972
Santander	T = 13.0 + 0.0025t	0.0025	0.0002	T = 122 − 0.041t	−0.041	0.00233
A Coruña	T = 13.2 + 0.0028t	0.0028	0.000064	N.S. (+)	0.0061	0.6424
Ourense	T = 6.5 + 0.0035t	0.0035	0.000007	T = 184 − 0.0476t	−0.0476	0.00305
Valladolid	T = 11.3 + 0.0022t	0.0022	0.0363	N.S. (+)	0.0035	0.495
Salamanca	T = 8.8 + 0.0063t	0.0063	0.0398	N.S. (−)	−0.0012	0.9265
Zamora	N.S. (+)	0.0006	0.8317	T = 54.8 − 0.042t	−0.042	0.002665
Burgos	N.S. (+)	0.001	0.7004	T = 27 + 0.0428t	0.0428	0.024354
Albacete	T = 11.7 + 0.0043t	0.0043	0.0175	N.S. (−)	−0.0033	0.6529

Table 2. *Cont.*

Province	Temperature Trend	Temperature Coefficient	Temperature *p*-Value	Precipitation Trend	Precipitation Coefficient	Precipitation *p*-Value
Ciudad real	T = 11.8 + 0.0063t	0.0063	0.0027	N.S. (+)	0.0082	0.4132
Toledo	T = 11.5 + 0.0074t	0.0074	0.0052	N.S. (−)	−0.0074	0.4645
Girona	T = 12 + 0.0047t	0.0047	0.01554	N.S. (−)	−0.0227	0.1918
Barcelona	T = 13.7 + 0.0042t	0.0042	0.003056	N.S. (−)	−0.0248	0.062
Castellón	T = 14.5 + 0.0051t	0.0051	0.007174	N.S. (+)	0.0042	0.7949
Jaén	N.S. (+)	0.0016	0.7098	T = 0.8 + 0.0647t	0.0647	0.0369
Sevilla	T = 17 + 0.004t	0.004	0.0028	N.S. (−)	−0.0227	0.0802
Málaga	T = 15 + 0.004t	0.004	0.000004	N.S. (−)	−0.0166	0.0802
Almería	T = 17.5 + 0.0026t	0.0026	0.0487	N.S. (−)	−0.0019	0.7477

N.S.: not significant.

Table 3. Summary of results of the Mann–Kendall trend test and Sen's Slope.

Province	Mann–Kendall Trend Test Temp.	Sen's Slope Temp.	Mann–Kendall Trend Test Preci.	Sen's Slope Preci.
Oviedo	a.h.: true	0.0026		
Santander	a.h.: true	0.0023	a.h.: true	−0.03
A Coruña	a.h.: true	0.0028		
Ourense	a.h.: true	0.0034	a.h.: true	−0.03
Valladolid	a.h.: true	0.0055		
Salamanca	a.h.: true	0.0055		
Zamora			a.h.: true	−0.022
Burgos			a.h.: true	0.04
Albacete	a.h.: true	0.0041		
Ciudad real	a.h.: true	0.0061		
Toledo	a.h.: true	0.0075		
Girona	a.h.: true	0.0043		
Barcelona	a.h.: true	0.0041		
Castellón	a.h.: true	0.0049		
Jaén			a.h.: true	0.03
Sevilla	a.h.: true	0.0039		
Málaga	a.h.: true	0.004		
Almería	a.h.: true	0.0024		

a.h.: alternative hypothesis.

3.3. ARIMA Modeling and Forecasting

The 29 differentiated temperature series allowed for the identification of ARIMA models. A summary of the resulting models obtained for each of the 29 temperature series is shown in the Table 4.

Table 4. ARIMA models of the 29 temperature series of peninsular Spain.

Serie	Model	Estimated Coefficients ($p \leq 0.05$)
Zaragoza	ARIMA $(1,1,1) \times (0,1,1)_{12}$	$W_t = 0.133W_{t-1} + 0.922a_{t-1} + 0.912a_{t-12} + a_t$ 0.019　　0.000　　0.000　　←*p*-v
Huesca	ARIMA $(1,1,1) \times (0,1,1)_{12}$	$W_t = -0.001 + 0.242W_{t-1} + 0.942a_{t-1} + 0.905a_{t-12} + a_t$ 0.000　　0.000　　0.000　　←*p*-v
Teruel	ARIMA $(1,0,0) \times (0,1,1)_{12}$	$Z_t = 0.302Z_{t-1} + 0.948a_{t-12} + a_t$ 0.000　　0.000　　←*p*-v
Oviedo	ARIMA $(1,0,0) \times (0,1,1)_{12}$	$Z_t = 0.024 + 0.17Z_{t-1} + 0.948a_{t-12} + a_t$ 0.000　　0.000　　←*p*-v
Santander	ARIMA $(1,0,0) \times (0,1,1)_{12}$	$Z_t = 0.022 + 0.221Z_{t-1} + 0.964a_{t-12} + a_t$ 0.000　　0.000　　←*p*-v
Pamplona	ARIMA $(1,0,0) \times (0,1,1)_{12}$	$Z_t = 0.013 + 0.19Z_{t-1} + 0.96a_{t-12} + a_t$ 0.000　　0.000　　←*p*-v
Vizcaya	ARIMA $(1,0,1) \times (0,1,1)_{12}$	$Z_t = 0.632Z_{t-1} + 0.466a_{t-1} + 0.939a_{t-12} + a_t$ 0.002　　0.044　　0.000　　←*p*-v
Gipuzkoa	ARIMA $(1,0,0) \times (0,1,1)_{12}$	$Z_t = 0.139Z_{t-1} + 0.938a_{t-12} + a_t$ 0.008　　0.000　　←*p*-v
Álava	ARIMA $(1,0,1) \times (0,1,1)_{12}$	$Z_t = 0.011 + 0.686Z_{t-1} + 0.535a_{t-1} + 0.935a_{t-12} + a_t$ 0.000　　0.012　　0.000　　←*p*-v

Table 4. *Cont.*

Serie	Model	Estimated Coefficients ($p \leq 0.05$)
A Coruña	ARIMA $(1,0,1) \times (0,1,1)_{12}$	$Z_t = 0.013 + 0.557Z_{t-1} + 0.349a_{t-1} + 0.96a_{t-12} + a_t$ 0.000 0.038 0.000 $\leftarrow p\text{-v}$
Pontevedra	ARIMA $(1,0,0) \times (0,1,1)_{12}$	$Z_t = -0.007 + 0.218Z_{t-1} + 0.936a_{t-12} + a_t$ 0.000 0.000 $\leftarrow p\text{-v}$
Ourense	ARIMA $(1,1,1) \times (0,1,1)_{12}$	$W_t = 0.205W_{t-1} + 0.949a_{t-1} + 0.959a_{t-12} + a_t$ 0.000 0.000 0.000 $\leftarrow p\text{-v}$
Lugo	ARIMA $(1,0,0) \times (0,1,1)_{12}$	$Z_t = 0.019 + 0.161Z_{t-1} + 0.936a_{t-12} + a_t$ 0.03 0.00 $\leftarrow p\text{-v}$
Valladolid	ARIMA $(1,0,0) \times (0,1,1)_{12}$	$Z_t = 0.019 + 0.206Z_{t-1} + 0.963a_{t-12} + a_t$ 0.000 0.000 $\leftarrow p\text{-v}$
Ávila	ARIMA $(1,0,0) \times (0,1,1)_{12}$	$Z_t = -0.05 + 0.177Z_{t-1} + 0.937a_{t-12} + a_t$ 0.000 0.000 $\leftarrow p\text{-v}$
Segovia	ARIMA $(1,0,0) \times (0,1,1)_{12}$	$Z_t = 0.209Z_{t-1} + 0.927a_{t-12} + a_t$ 0.000 0.000 $\leftarrow p\text{-v}$
Albacete	ARIMA $(1,1,1) \times (0,1,1)_{12}$	$W_t = 0.156W_{t-1} + 0.97a_{t-1} + 0.943a_{t-12} + a_t$ 0.000 0.000 0.000 $\leftarrow p\text{-v}$
Ciudad real	ARIMA $(1,1,1) \times (0,1,1)_{12}$	$W_t = -0.0004 + 0.25W_{t-1} + 0.985a_{t-1} + 0.918a_{t-12} + a_t$ 0.000 0.000 0.000 $\leftarrow p\text{-v}$
Cuenca	ARIMA $(1,0,0) \times (0,1,1)_{12}$	$Z_t = 0.233Z_{t-1} + 0.923a_{t-12} + a_t$ 0.000 0.000 $\leftarrow p\text{-v}$
Cáceres	ARIMA $(1,0,0) \times (1,1,1)_{12}$	$Z_t = 0.025 + 0.237Z_{t-1} + 0.047z_{t-12} + 0.941a_{t-12} + a_t$ 0.393 0.000 $\leftarrow p\text{-v}$
Tarragona	ARIMA $(1,0,0) \times (0,1,1)_{12}$	$Z_t = -0.03 + 0.324Z_{t-1} + 0.8986a_{t-12} + a_t$ 0.000 0.000 $\leftarrow p\text{-v}$
Jaén	ARIMA $(1,0,0) \times (0,1,1)_{12}$	$Z_t = 0.233Z_{t-1} + 0.935a_{t-12} + a_t$ 0.000 0.000 $\leftarrow p\text{-v}$
Sevilla	ARIMA $(1,0,0) \times (0,1,1)_{12}$	$Z_t = 0.031 + 0.258Z_{t-1} + 0.921a_{t-12} + a_t$ 0.000 0.000 $\leftarrow p\text{-v}$
Granada	ARIMA $(1,1,1) \times (0,1,1)_{12}$	$W_t = 0.215W_{t-1} + 0.977a_{t-1} + 0.968a_{t-12} + a_t$ 0.000 0.000 $\leftarrow p\text{-v}$
Málaga	ARIMA $(1,1,1) \times (0,1,1)_{12}$	$W_t = 0.266W_{t-1} + 0.915a_{t-1} + 0.969a_{t-12} + a_t$ 0.000 0.000 $\leftarrow p\text{-v}$
Almería	ARIMA $(1,1,1) \times (0,1,1)_{12}$	$W_t = 0.229W_{t-1} + 0.975a_{t-1} + 0.938a_{t-12} + a_t$ 0.000 0.000 0.000 $\leftarrow p\text{-v}$
Córdoba	ARIMA $(0,0,1) \times (0,1,1)_{12}$	$Z_t = 0.029 - 0.277a_{t-1} + 0.933a_{t-12} + a_t$ 0.000 0.000 $\leftarrow p\text{-v}$
Cádiz	ARIMA $(0,0,1) \times (0,1,1)_{12}$	$Z_t = 0.02 - 0.28a_{t-1} + 0.942a_{t-12} + a_t$ 0.000 0.000 $\leftarrow p\text{-v}$
Huelva	ARIMA $(1,0,1) \times (0,1,1)_{12}$	$Z_t = -0.008 + 0.7Z_{t-1} + 0.447a_{t-1} + 0.942a_{t-12} + a_t$ 0.000 0.001 0.000 $\leftarrow p\text{-v}$

p-v: *p*-value.

The ARIMA model of prediction without the constant that allowed for the estimation of the values of the variable at a future time (t + 1) based on their values at previous instants (t, t − 1, …) for the temperature series of Zaragoza, Huesca, Ourense, Albacete, Ciudad Real, Granada, Málaga, and Almería resulted in the following:

$$\text{ARIMA } (1,1,1) \times (0,1,1)_{12}: \; W_t = \varnothing W_{t-1} - \theta a_{t-1} - \vartheta a_{t-12} + a_t; \; W_t = Z_t - Z_{t-1}; \; Z_t = X_t - X_{t-12}$$
$$Z_t = Z_{t-1} + \varnothing(Z_{t-1} - Z_{t-2}) - \theta a_{t-1} - \vartheta a_{t-12} + a_t \tag{1}$$
$$X_t = X_{t-12} + (1 + \varnothing)(X_{t-1} - X_{t-13}) - \varnothing(X_{t-2} - X_{t-14}) - \theta a_{t-1} - \vartheta a_{t-12} + a_t$$

For the temperature series of Teruel, Oviedo, Santander, Pamplona, Gipuzkoa, Pontevedra, Lugo, Valladolid, Ávila, Segovia, Cuenca, Tarragona, Jaén, and Sevilla, the prediction model without the constant was

$$\text{ARIMA } (1,0,0) \times (0,1,1)_{12}: \; Z_t = \varnothing Z_{t-1} + \vartheta a_{t-12} + a_t; \; Z_t = X_t - X_{t-12}$$
$$X_t = X_{t-12} + \varnothing(X_{t-1} - X_{t-13}) - \vartheta a_{t-12} + a_t \tag{2}$$

For the temperature series of Vizcaya, Álava, A Coruña, and Huelva, the prediction model without the constant was:

$$\text{ARIMA} (1, 0, 1) \times (0, 1, 1)_{12} : \; Z_t = \varnothing Z_{t-1} - \theta a_{t-1} - \vartheta a_{t-12} + a_t$$
$$X_t = X_{t-12} + \varnothing(X_{t-1} - X_{t-13}) - \theta a_t - \vartheta a_{t-12} + a_t \tag{3}$$

For the Cáceres temperature series, the prediction model without the constant was

$$\text{ARIMA} (1, 0, 0) \times (1, 1, 1)_{12} : \; X_t = X_{t-12} + \varnothing(X_{t-1} - X_{t-13}) + \alpha(X_{t-12} - X_{t-24}) - \vartheta a_{t-12} + a_t \tag{4}$$

For the temperature series of Córdoba and Cádiz, the prediction model without the constant was

$$\text{ARIMA} (0, 0, 1) \times (0, 1, 1)_{12} : \; X_t = X_{t-12} - \theta a_{t-1} - \vartheta a_{t-12} + a_t \tag{5}$$

where in Equations (1)–(5), $\varnothing, \theta, \vartheta,$ and α represent the estimated coefficient for each model.

A summary of the resulting models obtained for each of the 27 precipitation series is shown in the Table 5.

Table 5. ARIMA models of the 27 precipitation series.

Serie	Model	Estimated Coefficients ($p \leq 0.05$)
Zaragoza	ARIMA $(0,0,0) \times (0,1,1)_{12}$	$Z_t = 0.951a_{t-12} + a_t$ 0.000 $\leftarrow p$-v
Teruel	ARIMA $(1,1,1) \times (0,1,1)_{12}$	$W_t = 0.108W_{t-1} + 0.976a_{t-1} + 0.936a_{t-12} + a_t$ 0.042 0.000 0.000 $\leftarrow p$-v
Oviedo	ARIMA $(1,0,0) \times (0,1,1)_{12}$	$Z_t = 0.015 + 0.113Z_{t-1} + 0.948a_{t-12} + a_t$ 0.011 0.000 $\leftarrow p$-v
Logroño	ARIMA $(1,0,0) \times (0,1,1)_{12}$	$Z_t = 0.127Z_{t-1} + 0.909a_{t-12} + a_t$ 0.0015 0.000 $\leftarrow p$-v
Pamplona	ARIMA $(1,0,0) \times (0,1,1)_{12}$	$Z_t = 0.116Z_{t-1} + 0.957a_{t-12} + a_t$ 0.001 0.000 $\leftarrow p$-v
Gipuzkoa	ARIMA $(0,0,0) \times (0,1,1)_{12}$	$Z_t = 0.928a_{t-12} + a_t$ 0.000 $\leftarrow p$-v
Álava	ARIMA $(0,0,0) \times (0,1,1)_{12}$	$Z_t = 0.925a_{t-12} + a_t$ 0.000 $\leftarrow p$-v
A Coruña	ARIMA $(1,0,0) \times (0,1,1)_{12}$	$Z_t = 0.116Z_{t-1} + 0.957a_{t-12} + a_t$ 0.003 0.000 $\leftarrow p$-v
Pontevedra	ARIMA $(1,0,0) \times (0,1,1)_{12}$	$Z_t = 0.1Z_{t-1} + 0.958a_{t-12} + a_t$ 0.015 0.000 $\leftarrow p$-v
Lugo	ARIMA $(1,0,0) \times (0,1,1)_{12}$	$Z_t = 0.272Z_{t-1} + 0.94a_{t-12} + a_t$ 0.000 0.000 $\leftarrow p$-v
Valladolid	ARIMA $(0,0,0) \times (0,1,1)_{12}$	$Z_t = 0.962a_{t-12} + a_t$ 0.000 $\leftarrow p$-v
Salamanca	ARIMA $(0,0,0) \times (0,1,1)_{12}$	$Z_t = 0.94a_{t-12} + a_t$ 0.000 $\leftarrow p$-v
Segovia	ARIMA $(1,0,0) \times (0,1,1)_{12}$	$Z_t = 0.124Z_{t-1} + 0.925a_{t-12} + a_t$ 0.035 0.000 $\leftarrow p$-v
Burgos	ARIMA $(0,0,0) \times (0,1,1)_{12}$	$Z_t = 0.935a_{t-12} + a_t$ 0.000 $\leftarrow p$-v
Soria	ARIMA $(1,0,0) \times (0,1,1)_{12}$	$Z_t = 0.167Z_{t-1} + 0.939a_{t-12} + a_t$ 0.001 0.000 $\leftarrow p$-v
Albacete	ARIMA $(0,1,1) \times (0,1,1)_{12}$	$Z_t = 0.968a_{t-1} + 0.945a_{t-12} + a_t$ 0.000 0.000 $\leftarrow p$-v
Toledo	ARIMA $(0,0,1) \times (0,1,1)_{12}$	$Z_t = -0.176a_{t-1} + 0.947a_{t-12} + a_t$ 0.000 0.000 $\leftarrow p$-v
Badajoz	ARIMA $(1,0,0) \times (0,1,1)_{12}$	$Z_t = 0.178Z_{t-1} + 0.934a_{t-12} + a_t$ 0.000 0.000 $\leftarrow p$-v
Tarragona	ARIMA $(0,0,0) \times (0,1,1)_{12}$	$Z_t = -0.354 + 0.935a_{t-12} + a_t$ 0.000 $\leftarrow p$-v
Lleida	ARIMA $(0,0,0) \times (0,1,1)_{12}$	$Z_t = 0.953a_{t-12} + a_t$ 0.000 $\leftarrow p$-v

Table 5. *Cont.*

Serie	Model	Estimated Coefficients ($p \leq 0.05$)
Valencia	ARIMA $(0,0,0) \times (0,1,1)_{12}$	$Z_t = 0.944a_{t-12} + a_t$ 0.000 $\leftarrow p\text{-v}$
Jaén	ARIMA $(1,0,0) \times (0,1,1)_{12}$	$Z_t = 0.205Z_{t-1} + 0.921a_{t-12} + a_t$ 0.000 0.000 $\leftarrow p\text{-v}$
Sevilla	ARIMA $(1,0,0) \times (0,1,1)_{12}$	$Z_t = 0.134Z_{t-1} + 0.964a_{t-12} + a_t$ 0.000 0.000 $\leftarrow p\text{-v}$
Granada	ARIMA $(1,0,0) \times (0,1,1)_{12}$	$Z_t = 0.121Z_{t-1} + 0.968a_{t-12} + a_t$ 0.000 0.000 $\leftarrow p\text{-v}$
Málaga	ARIMA $(0,0,1) \times (0,1,1)_{12}$	$Z_t = -0.117a_{t-1} + 0.971a_{t-12} + a_t$ 0.001 0.000 $\leftarrow p\text{-v}$
Almería	SARIMA $(0,1,1)_{12}$	$Z_t = 0.97a_{t-12} + a_t$ 0.000 $\leftarrow p\text{-v}$
Córdoba	ARIMA $(1,0,0) \times (1,1,1)_{12}$	$Z_t = 0.21 + 0.16Z_{t-1} + 0.12Z_{t-12} + 0.94a_{t-12} + a_t$ 0.004 0.04 0.000 $\leftarrow p\text{-v}$

p-v: *p*-value.

The ARIMA model of prediction without the constant that allowed for the estimation of the values of the variable at a future time ($t + 1$) based on their values at previous instants (t, t–1, …) for the precipitation series of Zaragoza, Gipuzkoa, Álava, Valladolid, Salamanca, Burgos, Tarragona, Lleida, Valencia, and Almería resulted in the following:

$$\text{SARIMA } (0,1,1)_{12}: \ Z_t = \vartheta a_{t-12} + a_t; \ Z_t = -_t - X_{t-12}$$
$$X_t = X_{t-12} + \vartheta a_{t-12} + a_t \tag{6}$$

For the Teruel precipitation series, the prediction model without the constant was

$$\text{ARIMA } (1,1,1) \times (0,1,1)_{12}: \ W_t = \varnothing W_{t-1} - \theta a_{t-1} - \vartheta a_{t-12} + a_t; \ W_t = Z_t - Z_{t-1}; \ Z_t = X_t - X_{t-12}$$
$$Z_t = Z_{t-1} + \varnothing(Z_{t-1} - Z_{t-2}) - \theta a_{t-1} - \vartheta a_{t-12} + a_t \tag{7}$$
$$X_t = X_{t-12} + (1+\varnothing)(X_{t-1} - X_{t-13}) - \varnothing(X_{t-2} - X_{t-14}) - \theta a_{t-1} - \vartheta a_{t-12} + a_t$$

For the precipitation series of Oviedo, Logroño, Pamplona, A Coruña, Pontevedra, Lugo, Segovia, Soria, Badajoz, Jaén, Sevilla, and Granada, the prediction model without the constant was

$$\text{ARIMA } (1,0,0) \times (0,1,1)_{12}: \ Z_t = \varnothing Z_{t-1} + \vartheta a_{t-12} + a_t; \ Z_t = -_t - X_{t-12}$$
$$X_t = X_{t-12} + \varnothing(X_{t-1} - X_{t-13}) - \vartheta a_{t-12} + a_t \tag{8}$$

For the precipitation series of Albacete, the prediction model without the constant was

$$\text{ARIMA } (0,1,1) \times (0,1,1)_{12}: \ Z_t = \theta a_{t-1} + \vartheta a_{t-12} + a_t; \ Z_t = -_t - X_{t-12}$$
$$X_t = X_{t-12} + \theta a_{t-1} + \vartheta a_{t-12} + a_t \tag{9}$$

For the precipitation series of Toledo and Málaga, the prediction model without the constant was

$$\text{ARIMA } (0,0,1) \times (0,1,1)_{12}: \ Z_t = \theta a_{t-1} + \vartheta a_{t-12} + a_t; \ Z_t = -_t - X_{t-12}$$
$$X_t = X_{t-12} + \theta a_{t-1} + \vartheta a_{t-12} + a_t \tag{10}$$

For the precipitation series of Córdoba, the prediction model without the constant was

$$X_t = X_{t-12} + \varnothing(X_{t-1} - X_{t-13}) + \alpha(X_{t-12} - X_{t-24}) - \vartheta a_{t-12} + a_t \tag{11}$$

where in Equations (6)–(11), $\varnothing, \theta, \vartheta, \text{ and } \alpha$ represent the estimated coefficient for each model.

4. Discussion

The homogeneity tests, according to [48], were considered valid for use in this study, because the removal of false detected inhomogeneities and the acceptance of inhomogeneous series affect each subsequent analysis (e.g., trend assessments and extreme analysis).

The study revealed the existence of a significant, positive trend in the temperature series of Oviedo, Santander, A Coruña, and Ourense with the magnitude from 0.002 to 0.003 belonging to study zone I. In the same zone, it was also observed that positive trends clearly prevailed over negative trends in the periods of the study. "The increase in global temperature is not homogeneously distributed on the surface, varying in magnitude between different regions and between different locations within the same region. These regional variations are also perceived in the behavior of extreme values and in the daily thermal amplitude, which exhibits negative trends in many regions of the globe, while in others the changes are of opposite sign or are not significant. The comparison between different papers is also complicated, since the periods of study, the variables analyzed, the stations of measurement selected and the time scale used (daily, monthly, seasonal or annual) do not coincide in most cases and the results show a high sensitivity to all these factors [46]". However, several authors detected a positive trend of temperatures in Spain, and despite the differences between the periods analyzed and the time scales, they found results almost similar to ours. González-Hidalgo et al. [49] identified a positive and significant global signal in the period 1951–2010 in the analysis of trends of mean monthly maximum temperatures (Tmax) and mean monthly minimum temperatures (Tmin) in peninsular Spain with the MOTEDAS database. Cruz et al. [50] found for the mean monthly temperatures of Galicia in the period of 1973–2004, there was a significant increase in the mean temperature in the months of January, March, May, June, and August, leaving February, April, and July close to significance. Brunet et al. [51] found a significant, positive trend for the spatial pattern of the northern zone of Spain and that the annual averages of the mean daily temperature had increased significantly in the period of 1805–2005. Del Rio et al. [52] highlighted the significant, positive trends for the mean monthly temperatures from 1961 to 2006 and revealed that the temperature had generally increased during all months and seasons of the year during the last four decades, and they also detected for the same period a significant, positive trend of mean monthly temperatures in the Cantabrian cornice and in the Galician massif in the months of March and June. It should be noted that of the fourteen series of mean monthly temperatures of **zone I**, only four series showed a significant, positive trend. Those were the temperature series of Oviedo, Santander, A Coruña, and Ourense; the remaining series did not present a significant trend. This shows the existence of what is called the "Hiatus", defined as the absence of a significant trend [49,53,54].

Our study revealed the existence of a significant, positive trend for the temperature series of Valladolid, Salamanca, Albacete, Ciudad Real, and Toledo with the magnitude from 0.004 to 0.007 in zone II, which is located in the Central Plateau. Positive trends in zone II clearly prevailed over negative trends in the periods of study as in the case of zone I. Several studies focused on the north and south plateau and the Spanish central system, examining the trends of the climatic variable temperature. Such studies found results almost similar to ours, despite the differences in the periods analyzed and the time scales. For example, Morales et al. [55] detected a positive trend at the 95% confidence level by analyzing the annual maximums and mean temperatures in winter for Castile and León in the period of 1945–1996. Del Río et al. [56] detected a positive trend of mean monthly maximum and minimum temperatures in every month of the year for Castile and León in the period 1961–1997. Labajo et al. [57] detected a positive trend of the mean annual minimum temperature for Castile and León in the period 1945–1994. Del Río et al. [58] found positive trends in the mean annual temperature for Castile and León in the period of 1961–1997.

The trends detected in zone III showed a significant, positive trend for the temperature series of Girona, Barcelona, and Castellón with a magnitude from 0.004 to 0.005 for the three

series. Other authors also detected a positive trend of temperatures in the Mediterranean strip despite the differences in the periods analyzed and the time scales. For example, Brunet et al. [12] detected a significant, positive trend for the Mediterranean strip (Barcelona, Valencia, Alicante, and Murcia) for annual maximum and minimum temperatures in the period of 1850–2003. El Kenawy et al. [59] detected the predominance of a significant, positive trend of annual maximum and minimum temperatures in the period of 1950–2006 for the Mediterranean strip (Tarragona, Girona, Lleida, Barcelona, and Castellón). Oñate et al. [60] detected a significant, positive trend of mean annual temperatures for Alicante since 1901.

The study zone IV showed a significant, positive trend for the temperatures series of Sevilla, Málaga, and Almería with a magnitude from 0.002 to 0.004.

Regarding precipitation, the study revealed the existence of a significant, negative trend for series of Santander and Ourense with a magnitude of −0.04 in zone I and for series of Zamora with a magnitude of −0.04 in zone II and a significant, positive trend for series of Burgos and Jaén with magnitude of 0.04 and 0.06, respectively, in zones II and IV. Regarding precipitation in peninsular Spain, in the analysis of the monthly, annual, and seasonal series, no significant trends were observed throughout the 20th century as pointed out by several studies [23,36,61–67]. However, Mosmann et al. [68] detected a statistically significant, positive trend in large areas of continental Spain in the analysis of precipitation series in 333 summer precipitation stations in the period of 1961–1990.Therefore, "when studies on precipitation trends in the peninsular Spain are contrasted, it is common to find discrepancies and contradictions in the results, even when it comes to trends related to the same period. The disagreements are usually due to the existence of multiple regional databases of precipitation stations with very variable density, often unpublished or with very restricted access, there being little coincidence between the series analyzed by different studies. Other causes may be differences in the statistical methods used, problems with the quality and homogenization of the data and the lack of a unified methodology to correct these problems and another complication that arises is that, due to the great spatial variability of the precipitation, changes in local precipitation are not necessarily representative of changes on a larger scale" [46]. However, there are several studies on precipitation trends in peninsular Spain and some results, coincide with the trend detected in our study area (zone I) despite the differences in the periods analyzed and the time scales, while others found different results from ours. For example, González-Hidalgo et al. [28] detected a negative trend of monthly precipitation in the month of March for the Galician massif, while the Cantabrian cornice presented a non-significant trend in the period of 1946–2005. Serrano et al. [69] detected a positive trend of mean monthly precipitation in the cold months and in summer during the period of 1919–1992 in Galicia and the Cantabrian coast. Cuadrat et al. [70] detected a negative trend of monthly precipitation for Zaragoza, Huesca, and Teruel in the period of 1950–2010. Esteban-Parra et al. [23] found a positive trend of annual precipitation for the Cantabrian stations in the period of 1880–1992. Serrano et al. [61] detected a non-significant trend in the Cantabrian cornice and the Galician massif in the analysis of annual precipitation in the period of 1921–1995. De Luis et al. [71] detected a negative trend of annual and seasonal precipitation in the period of 1951–2000 in the Ebro basin, including the territories of the autonomous communities of the Basque Country, Cantabria, Castile and León, La Rioja, Navarra, Aragón, Cataluña, Castilla–La Mancha, and the Comunidad Valenciana.

In zone II of the study, negative trends prevailed over positive trends in the periods of study. Several studies detected negative trends in precipitation at the level of peninsular Spain [24,25,72,73] despite the differences in the periods analyzed and the time scales. At the level of the plateau, Del Río et al. [58] observed a statistically significant, negative trend in March in the precipitation for Castile and León during three seasons (winter, spring, and autumn) in the period of 1961–1997. González-Hidalgo et al. [27,28] detected a significant, negative trend with the total precipitation during the month of March for the north–south

plateau and the central system of peninsular Spain in the analysis of monthly precipitation in the period of 1946–2005.

In zone III, negative trends prevailed over positive trends in the periods of study. De Luis et al. [74] observed that the negative trend predominated in the analysis of the annual precipitation in the Valencian Community during the period of 1961–1990. Álvarez et al. [75] detected a slight statistically insignificant, negative trend in the mean annual precipitation series of the Region of Murcia in the period of 1914–2013. Guirado and Bermúdez [76] showed a slight negative trend of annual precipitation in Murcia in the period of 1933–2008. González-Hidalgo et al. [77] detected for the month of March a significant, negative trend for monthly precipitation that affected the entire Mediterranean strip in the period of 1951–2000. Romero et al. [78] detected a negative trend of daily precipitation in western Catalonia in the period of 1964–1993. Lana et al. [79] detected a significant, negative trend of daily precipitation in Cataluña in the period of 1950–2000. De Luis et al. [80] detected a significant, negative trend of annual precipitation in the Valencian Community in the period of 1961–1990.Similarly to us, Moreno and Martín-Vide also detected a negative trend in precipitation in the Mediterranean strip, while Quereda et al., in an analysis of 11 long series, found an increase in Cataluña and Castellon [81].

In zone IV, no negative or positive trend clearly prevailed in the periods of study, and the authors González-Hidalgo JC et al. also mentioned that "no homogeneous or global behavior of monthly precipitation trends was observed" in the Mediterranean strip of peninsular Spain [77].

Several authors have conducted studies for predictions with ARIMA modelling [82,83]. Temperature and precipitation data recorded in 47stations from different climatic zones of peninsular Spain were used to create suitable ARIMA models. Of the 47 temperature series, only 29 complied with the contrasts of the randomness of Box–Pierce and heteroscedasticity for constant variance; comparing the first and second half of the series and the 47 precipitation series, only 27 complied with these contrasts.

In addition, of the 29 temperature series and 27 precipitation series, the coefficients of the autocorrelation functions for multiple lags of the seasonal period were significantly different from zero. Therefore, a seasonal order differencing was made. Thus, $D = 1$. In order to establish the best ARIMA models for temperature and precipitation series, we used parameters p and q between 0 and 1 for optimization. All the ARIMAs of the 29 temperature series and 27 precipitation series were selected with the lowest possible RMSE error (root mean squared error). The RMSE ranged from 0.931206 (corresponding to the Almería temperature series) to 1.64402 (corresponding to the Teruel temperature series). For the precipitation series, the RMSE varied from 21.99 (corresponding to the Almería series) to 98,978 (corresponding to the Pontevedra series). Lastly, the ARIMA models obtained in Tables 4 and 5 could be beneficial in numerous applications where the observed temperature records are quite short or incomplete, or lack spatial coverage [84]. Moreover, the errors did not exceed 3 °C for the monthly average in temperatures and 20 mm in rainfall (see Figure 2a,b and Figure 3a,b); therefore, they can be useful for local short-term predictions (12 months) in practical situations, such as forest fires and pests and diseases in wild plants or cultivated and agricultural crops.
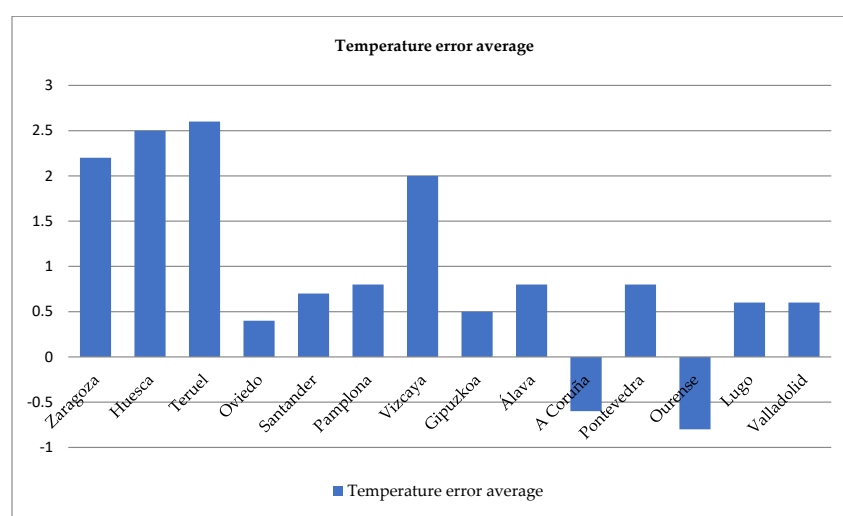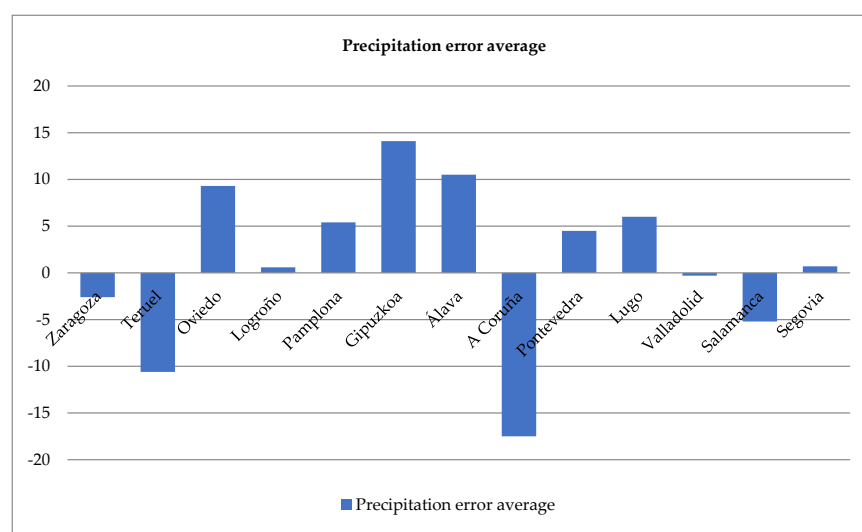
(**a**)
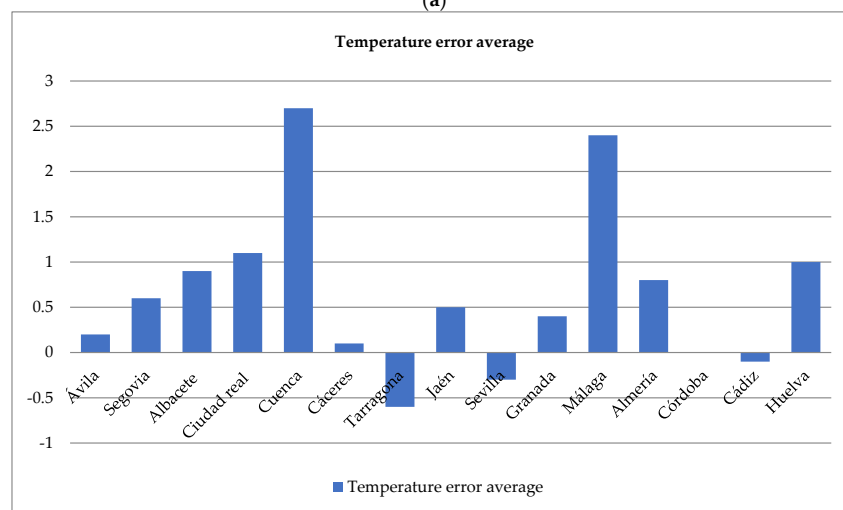
(**b**)

Figure 2. Temperature error average. The errors did not exceed 3 °C for the monthly average in temperatures in (**a**) either in (**b**).

(**a**)
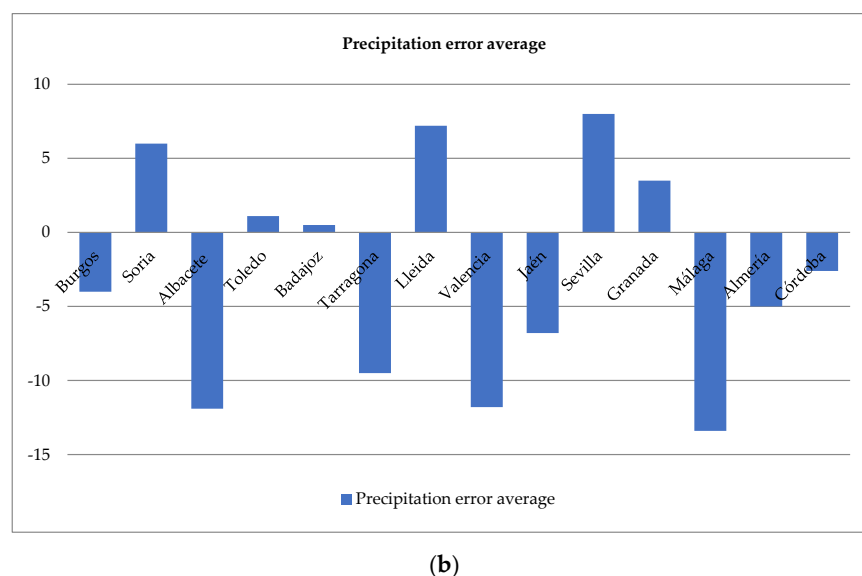
Figure 3. *Cont.*

(b)

Figure 3. Precipitation error average. The errors did not exceed 20 mm for the monthly average in precipitation in (**a**) either in (**b**).

5. Conclusions

The Box–Jenkins methodology allowed us to model the variations in temperatures and precipitations produced over time in the 47 provinces of peninsular Spain by grouping provinces into four zones. In the trend analysis of the 47 temperature series, only 34.04% showed a significant, positive trend. Among the 47 temperatures series in peninsular Spain, it was possible to correctly adjust a model for 29 series (or 61.7%), while the remaining 18 series (or 38.3%) did not correctly adjust. In the trends analysis of the 47 precipitation series, only those of Santander, Ourense, and Zamora (or a total of 6.3%) presented a significant, negative trend, while the precipitation series of Burgos and Jaén (4.2%) presented a significant, positive trend. Among the 47 precipitations series in peninsular Spain, it was possible to correctly adjust a model for 27 series (or 57.4%), while the remaining 20 series (or 42.6%) did not correctly adjust to a model.

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