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Trend Analysis of Meteorological Parameters of Adelaide, South Australia

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Abstract

The yearly as well as seasonal trends of four atmospheric parameters gathered for the period 1981-2016 were examined in this study for ten weather stations around Adelaide city, South Australia. The non-parametric Mann-Kendall and Sen's slope estimator techniques were utilized to establish the pattern of trend. Increasing trends were observed in the maximum and minimum temperature in the summer, spring and annual seasons. In addition, no considerable trend was observed in rainfall distribution. Solar radiation revealed a reducing trend in the winter, spring and annual seasons. Considerably rising trends had actually been observed for minimum as well as maximum temperature in Adelaide. An insignificantly increasing trend was observed in the rainfall throughout the duration of 1981-2016 just in the summertime as well as in the autumn season. In addition, a dramatically lowering trend in the solar radiation was observed throughout the autumn period, while majority of the trends in the various other periods had not shown any kind of considerable variation. The surge in the minimum as well as maximum temperature of the city was attributed to the climate change phenomenon brought on by growing population and also fast urbanization in the recent past.

Keywords: Adelaide; Meteorological parameters; Trend analysis; Mann-Kendall; Sen's slope

1. Introduction

Climate change can be signified as the most influencing response in the environment that took place over much longer periods of time. Although climate change is a worldwide sensation, its influence can commonly differ from area to area (Trajkovic and Kolakovic, 2009). Hence, the evaluation of modifications in the atmospheric parameters at the regional range is really vital and also plays a significant role in predicting climate change and educating ourselves for taking adequate precautions.

Different researches had been performed in the recent past on potential impact of climate trends around the world. Yunling and Yiping (2005) assessed climate change trends in China for the duration 1960-2000 at 19 stations along the Lancang River with the historical information of month-to-month air temperature level and also rainfall data. They observed a rise in temperature level in the inferior reaches of Lancang River and also reduction in rainfall in the top reaches. Deni *et al.* (2008) observed some trace adjustments in the completely dry as well as damp spells over Peninsular Malaysia based upon the day-to-day rain information from 20 rain stations that included 4 sub-regions through 1975 to 2004. Based upon everyday rain information for 10 rain-gauged stations over the duration of 1971-2005, Zin *et al.* (2010) assessed the adjustments in extremes of yearly rainfall in Peninsular Malaysia making use of 8 indices. They observed that the yearly spatial pattern for this region was significantly affected by the northeast gale in terms of the peak values for most of the indices during that period. Suhaila *et al.* (2010) examined the trends and patterns in Peninsular Malaysia of 5 chosen rain indices based upon the everyday rain information from 1975 to 2004. The conclusion of their research study recommended that the rain patterns in Peninsular Malaysia were quite impacted by the north-east gale as reported with larger adjustments in the rain indices.

Karaburun *et al.* (2011) evaluated the advancement of yearly, seasonal and also month-to-month mean, minimum as well as maximum temperature in Istanbul from 1975 to 2006 making use of the Mann-Kenadall as well as Sen's technique. Gocic and Trajokovic (2013) examined the yearly as well as seasonal patterns of 7 atmospheric variables for twelve climate stations in Serbia through 1980-2010. They observed boosting patterns in both yearly and seasonal minimum as well as maximum air temperature, significant reduction the relative humidity during summertime and autumn, and also considerable enhancement in the vapor pressure during springtime, summer season as well as autumn. No trends were observed in the summertime and also winter season for the rainfall distribution. Sayemuzzaman and Jha (2014) carried out spatial and temporal pattern evaluation of the yearly as well as seasonal time series of a collection of rainfall information consistently dispersed over 249 stations throughout the North Carolina, USA over the duration of 1950-2009. They observed a radical shift throughout 1960-1970 in many components; most significantly, the irregularity in the rainfall was represented by the oscillation indices for North Carolina. Beharry *et al.* (2015) examined the in situ temperature levels as well as rainfall datasets for the Caribbean island, Trinidad for 1961-2010 making use of the RClimDex software program as well as the Mann-Kendall examination for trends. They reported that the 1980s was the wettest season followed by successive completely dry days based on a day-to-day strength index throughout the years 2001-2010. Gajbhiye *et al.* (2016) assessed the regular monthly, seasonal as well as yearly rainfall patterns for the rain information of the Sindh river basin through 1901-2002 as well as 1942-2002. Their evaluation recommended a considerable rise in the pattern of rains in the Sindh river container during 1991-2002. Almeida *et al.* (2017) evaluated the spatio-temporal irregularity of rains and also temperature level (minimum, maximum as well as average) trends at 47 stations throughout the Brazilian Legal Amazon through 1973-2013. They observed a favorable trend of the annual range in between damp and also completely dry period rains in some stations, triggered because of a raising trend in the damp period rainfall. Muhire *et al.* (2018) used a variety of analytical strategies targeted at evaluating the size of the forecasted mean rain and also variety of stormy days over Rwanda on month-to-month, seasonal as well as yearly time ranges through 2015-2050. They observed that the variety of stormy days lowered in the main plateau as well as the south-eastern bogs, while the south-west, the north-west and also north-east areas had a raising pattern of stormy days.

From the above testimonial of literary works, it appears that trend evaluation on atmospheric parameters has actually been performed by scientists in different parts of the world. As far as the authors' knowledge is concerned, very few studies have been carried out on the trend analysis of meteorological parameters in South Australia. Chowdhury *et al.* (2015) evaluated the patterns as well as step adjustments in observed yearly as well as seasonal rains throughout South Australian area. They observed both upward as well as downward patterns in the Northern and Yorke area. Seasonally, austral springtime as well as summertime rains showed raising patterns in a lot of the areas whereas fall and also winter month's rains revealed lowering trends. Kamruzzaman *et al.* (2017) explored for the proof of modifications in the statistical distribution of yearly total and also yearly average of regular monthly day-to-day maxima in the rainfall records of 7 stations of South Australia for a period of 50 to 137 years. The month-to-month trends do not give any kind of particular proof of regular trend or any type of adjustments in the seasonal pattern, however a weak proof of rise of irregularity of rains is observed based upon the permutation tests. Earlier research studies carried out on South Australia concentrate just on the rains pattern variant.

Although, pattern evaluation of rains of South Australia had actually been researched, studies relating to the pattern evaluation of atmospheric parameters such as temperature, rainfall and solar radiation of Adelaide city are very limited. The purpose of this research study is to comprehend the variant in the trend of temperature, rainfall and solar radiation of the city based upon long-term meteorological records. In this study, the irregularity of 4 meteorological parameters at 10 weather stations around Adelaide city based upon 36 years data (1981-2016) has actually been evaluated, making use of Mann-Kendall analysis and also Sen's slope estimator. The specific objectives of the present study are: (1) to analyze and comprehend the trend characteristics of the selected meteorological variables in detail; and (2) further to quantify the significance of modifications by making use of Sen's slope estimator and Mann-Kendall analysis.

2. Materials and Methods

2.1 Study Area and Data Collection

Information for maximum temperature (T_{max}), minimum temperature (T_{min}), rainfall (R) and also everyday solar radiation (S) were gathered from the website of Australian Bureau of Meteorology for 10 stations situated in South Australia. While minimum temperature, maximum temperature, and also rainfall information were gathered from 1981-2016 (36 years), the everyday solar radiation information was gathered from 1991-2016 (26 years). The spatial distribution of the stations was provided in Figure 1 while the geographical coordinates of the stations was showed in Table 1.

The seasonal meteorological parameters were computed by averaging the monthly available data for each of the 10 stations. The four seasons were fairly observable on the continent as summer (December – February); autumn (March – May); winter (June – August) and spring (September – November). Table 2 summarized the calculated mean values with standard deviation for the selected four variables during the observed period.

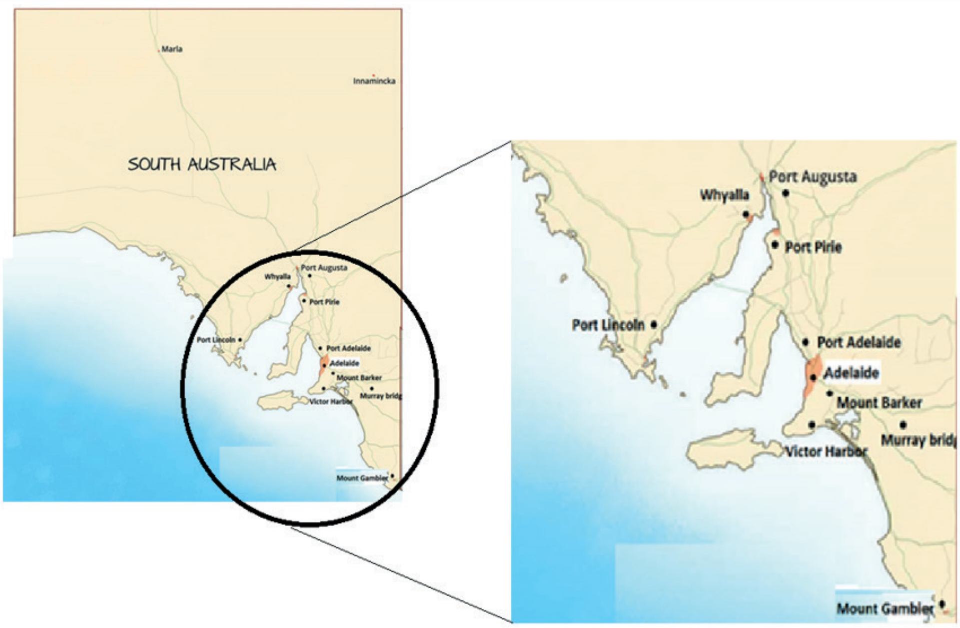


Figure 1. Spatial distribution of meteorological stations located around Adelaide city

Table 1. Geographical coordinates of the meteorological stations

Sl. No	Station	Latitude (S)	Longitude (E)
1	Adelaide	34⁰55'	138⁰35'
2	Mount Barker	35⁰08'	138⁰86'
3	Mount Gambier	37⁰82'	140⁰78'
4	Murray Bridge	35⁰13'	139⁰26'
5	Port Adelaide	34⁰84'	138⁰50'
6	Port Pirie	33°17'	138⁰00'
7	Port Augusta	32⁰49'	137⁰78'
8	Whyalla	33⁰03'	137⁰57'
9	Victor Harbor	35⁰55'	138⁰61'
10	Port Lincoln	34⁰72'	135⁰86'

Table 2. Mean values with standard deviation of the meteorological variables used in this study at twelve weather stations

Stations	Maximum temperature (⁰C)	Minimum temperature (⁰C)	Rainfall (mm)	Solar radiation (MJ/m^2)
Adelaide	22.45 ± 5.18	12.27 ± 3.59	41.53 ± 31.72	17.43 ± 7.26
Mount Barker	20.59 ± 5.33	8.59 ± 2.82	60.75 ± 47.21	16.92 ± 7.11
Mount Gambier	19.37 ±4.56	8.59 ± 2.41	59.34 ± 39.47	15.36 ± 6.92
Murray Bridge	23.19 ± 4.93	9.92 ± 3.45	30.67 ± 23.45	17.32 ± 7.00
Port Adelaide	21.71 ± 4.86	11.73 ± 3.44	36.54 ± 27.32	17.76 ± 7.23
Port Pirie	22.18 ± 6.45	10.47 ± 4.04	26.48 ± 21.75	18.71 ± 6.88
Port Augusta	23.68 ± 5.88	7.58 ± 4.45	28.05 ± 25.64	19.20 ± 6.76
Whyalla	22.87 ± 4.7	10.9 ± 3.77	26.48 ± 21.75	18.85 ± 6.77
Victor Harbor	18.25 ± 2.86	12.59 ± 2.41	56.47± 42.39	16.54 ± 6.73
Port Lincoln	21.64 ± 3.51	11.85 ± 3.00	25.75 ± 22.53	16.94 ± 6.44

The mean maximum temperature varied from 18.25 °C to 23.68 °C, and the mean minimum temperature varied from 7.58 °C to 12.95 °C. The mean rainfall values varied from 25.75 mm to 60.75 mm, and the mean solar radiation varied from 15.36 MJ/m^2 to 19.20 MJ/m^2. The standard deviation values were very much similar for all the stations for minimum temperature, maximum temperature and solar radiation. The standard deviation values for rainfall varied from 21.75 mm to 47.21 mm indicating that the rainfall distribution was likely to be skewed in the chosen time period.

2.2 Trend Analysis Methods

2.2.1 Mann-Kendall Test

As generally known as a non-parametric test, the Mann-Kendall test do not call for the information to be dispersed usually. By virtue of the inhomogeneous time collection, this test was effective in reducing sensitivity levels to sudden breaks (Jaagus, 2006). The key aspect of the test is the definition of a null theory H0 for the deseasonalised information (X_1, X_2, X_3... X_n) of *n* are independent and identically dispersed arbitrary variables. Further, the alternative theory H_1 of a two-sided test proposes unequal distributions of X_k and X_j for all k, j ≤ n, with k ≠ j. The test statistic S, is computed utilizing Eqn. (1) and (2), which is asymptotically normal and has mean zero with a variance as calculated by Eqn. (3),

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn(x_i - x_j) \quad (1)$$

$$sgn(x_i - x_j) = \begin{cases} +1 \; if \; (x_j - x_k) > 0 \\ 0 \; if \; (x_j - x_k) = 0 \\ -1 \; if \; (x_j - x_k) < 0 \end{cases} \quad (2)$$

.....

$$\mathrm{Var(S)} = \frac{[n(n-1)(2n+5) - \sum_t t(t-1)(2t+5)]}{18} \quad (3)$$

The notation t is the extent of any given time, and $\sum_t$ denotes the summation over all ties. In cases where the sample size n>10, the standard normal variable Z is computed using Eqn. (4):

$$Z = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} \; if \; S > 0 \\ 0 \quad if \; S = 0 \\ \frac{S+1}{\sqrt{Var(S)}} \; if \; S < 0 \end{cases} \quad (4)$$

The growing trends are represented by the positive values of Z while negative values indicate downward trends. Based on the standard normal cumulative distribution tables for an absolute value of Z greater than $Z_{t-1/2}$, the null hypothesis is to be precluded during the screening of either rising or falling monotonic trends (Modarres and da Silva 2007). In this study, significance levels of α = 0.01 and 0.05 have been used.

2.2.2 Sen's slope estimator

If the tie series data possesses a linear trend, a simple non-parametric procedure developed by Sen (1968) is used to estimate the true slope (changer per unit time). For N pairs of dataset, the slope estimates can be initially computed as:

$$Q_i = \frac{x_i - x_j}{j-k} \quad \text{for i=1,……N} \quad (5)$$

Where x_j and x_k denote data values at times j and k (j > k). Generally, Sen's estimator of slope is defined as the median of these N values. If N is odd, Sen's estimator takes the form as;

$$Q_{med} = Q_{[(N+1)/2]} \quad (6)$$

While if N is even, the median (Sen's estimator) is represented by

$$Q_{med} = 0.5 * [Q_{[N/2]} + Q_{[(N+2)/2]})] \quad (7)$$

After this, a two-sided test is to be used at the 100 (1-α) % confidence interval to test this Q_{med} from which the true slope can be estimated with the non-parametric test (Partal and Kahya 2006). In this study, two different confidence levels (α = 0.01 and 0.05) are used to calculate the confidence interval as follows:

$$C_\alpha = Z_{1-\frac{\alpha}{2}} \sqrt{Vas(S)} \quad (8)$$

Where Var(S) can be obtained from Eqn. (3), and Z1-α/2 is taken from the standard normal distribution.

Two intermediate terms are to be defined as M_1 = (N-Cα) /2 and M_2 = (N+ Cα) /2 based on the computed confidence interval limits. The M_1^{th} largest and the $(M+1)^{th}$ largest of the N ordered slope estimates (Q_i) are taken as the lower and upper limits of the confidence interval (Q_{min} and Q_{max}). In case if the values of M_1 and M_2 are not turned as whole numbers, then the corresponding lower and upper limits are to be estimated by interpolation (Salmi *et al.,* 2002).

3. Results and Discussion

3.1 Trends in the Meteorological Variables

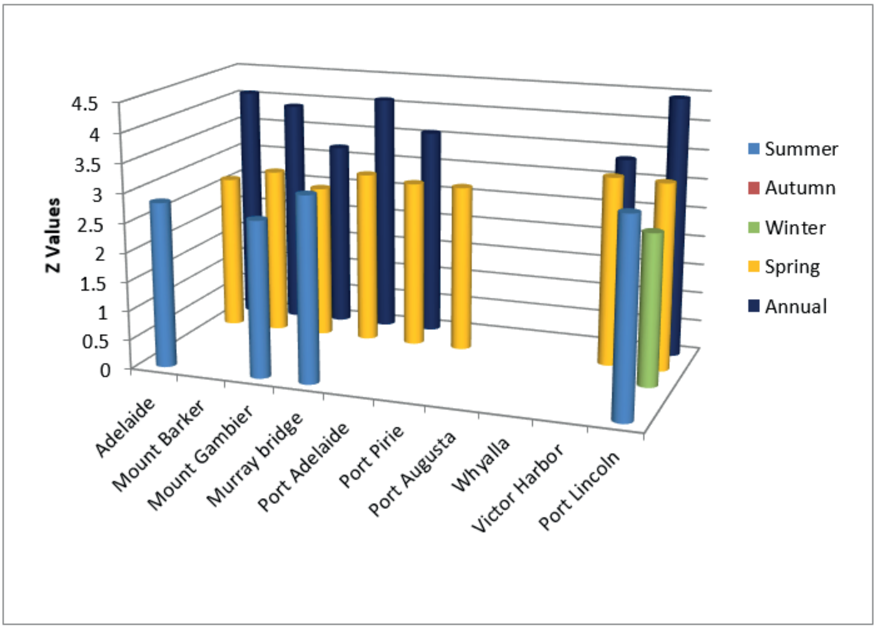
The results of applying the statistical tests for estimating the seasonal and annual T_{max} for the period of 1981-2016 was presented in Table 3.

Table 3. Statistical test results for the seasonal and annual T_{max} for the period 1981-2016

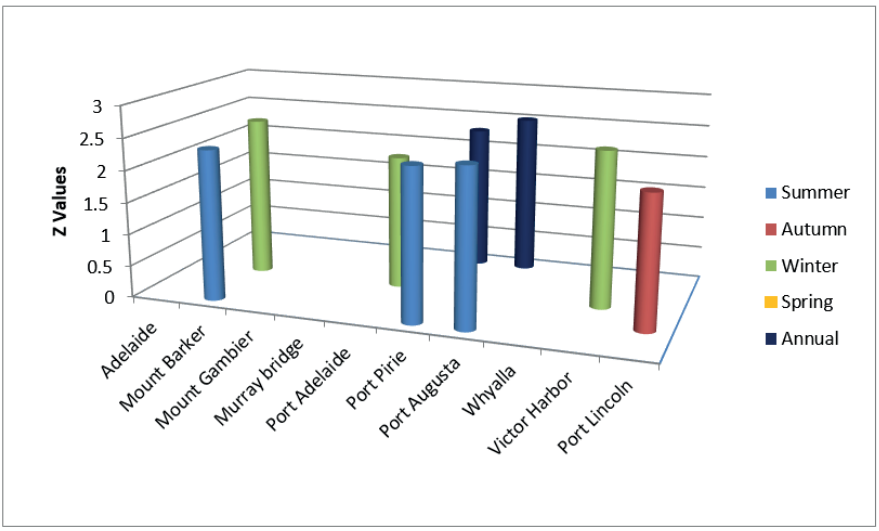
Station	Test	Trends				
		Summer	Autumn	Winter	Spring	Annual
Adelaide	Z	2.82**	1.73	1.77	2.66**	4.07**
	Q_{med}	0.059**	0.028	0.017	0.059**	0.059**
Mount Barker	Z	2.36*	1.44	2.51*	2.86**	3.88**
	Q_{med}	0.044*	0.033	0.025*	0.059**	0.04**
Mount Gambier	Z	2.67**	0.93	1.64	2.63**	3.19**
	Q_{med}	0.052**	0.013	0.012	0.043**	0.028**
Murray Bridge	Z	3.16**	1.72	1.05	2.94**	4.10**
	Q_{med}	0.062**	0.037	0.014	0.069**	0.042**
Port Adelaide	Z	1.89	1.59	2.09*	2.85**	3.57**
	Q_{med}	0.041	0.023	0.016*	0.058**	0.033**
Port Pirie	Z	2.37*	0.61	1.01	2.85**	2.27*
	Q_{med}	0.048*	0.011	0.012	0.08**	0.028*
Port Augusta	Z	2.44*	0.58	-0.2	1.92	2.5*
	Q_{med}	0.046*	0.005	-0.002	0.047	0.025*
Whyalla	Z	-0.48	0.14	0.86	1.05	0.25
	Q_{med}	-0.017	0.001	0.012	0.026	0.005
Victor Harbor	Z	1.29	1.61	2.44*	3.23**	3.35**
	Q_{med}	0.019	0.022	0.02*	0.039**	0.021**
Port Lincoln	Z	3.3**	2.07*	2.58**	3.2**	4.44**
	Q_{med}	0.046**	0.033*	0.024**	0.058**	0.042**

Z:Mann-Kendall test, Q_{med}: Sen's slope estimator; *Statistically significant trends at the 5% significance level; ** Statistically significant trends at the 1% significance level.

It was observed from Table 3 that throughout summertime, a few stations at Adelaide city such as Mount Gambier, Murray Bridge, and also Port Lincoln revealed substantially enhancing trend in T_{max}, and stations at Mount Barker, Port Pirie and also Port Augusta revealed insignificantly enhancing trend. Therefore, 40% of the stations revealed considerably enhancing trend at 1% significance level, as well as 30% of the stations revealed substantially boosting pattern at 5% significance level, throughout the summer season. Throughout autumn, the station at Port Lincoln showed partially boosting pattern in T_{max}. Throughout wintertime, stations at Mount Barker, Port Adelaide, and also Victor Harbor showed partially enhancing trend, while the station at Port Lincoln revealed substantially enhancing trend in T_{max}, suggesting that just 10% of the stations revealed substantially raising trend in T_{max} level at 5% significance level. Throughout springtime, stations at Adelaide city, Mount Barker, Mount Gambier, Murray Bridge, Port Adelaide, Port Pirie, Victor Harbor, as well as Port Lincoln revealed an enhancing trend in T_{max}. Therefore, 80% of the stations situated around Adelaide revealed considerably boosting pattern with 1% significance level in springtime for the period 1981-2016. In the yearly pattern, some stations at Adelaide city such as Mount Barker, Mount Gambier, Murray Bridge, Port Adelaide, Victor Harbor as well as Port Lincoln revealed dramatically enhancing pattern each year. Stations at Port Pirie as well as Port Augusta revealed partially raising pattern in T_{max} level each year. Hence, 70% as well as 20% of the stations revealed substantially raising pattern throughout the yearly duration at 1% and 5% significance level. The stations revealed enhancing pattern in T_{max} level at significance levels of 1% and 5% in the summertime, autumn, winter season, springtime and also every year was revealed in Figures 2a and 2b. In essence, 40% of the stations in summertime, 10% of the stations in wintertime, and 80% of the stations in springtime revealed a raising pattern in T_{max} level either with 1% or 5% significance levels. Therefore, the T_{max} showed an increasing trend in the Adelaide city except during winter. This was substantiated by the truth that 70% of the stations revealed a yearly raising trend in T_{max} level.



(a)



(b)

Figure 2. Stations showed increasing trend in Tmax at significance levels of (a) 1% and (b) 5% in the summer, autumn, winter, spring and annual seasons.

Table 4 revealed the outcomes of the statistical tests for the seasonal and also yearly level of T_{min} through 1981-2016. It was observed from Table 4 that throughout summertime, there was a considerable boost in the trend at Port Adelaide, Port Augusta, Whyalla and also Port Lincoln stations. Stations situated at Adelaide city, Mount Barker, Mount Gambier, Murray Bridge as well as Victor Harbor showed a partially raising trend in the T_{min} level. Therefore, 40% and also 50% of the stations indicated a statistically significant trend at 1% and also 5% significance level throughout the summertime. Throughout autumn, just stations at Mount Barker as well as Victor Harbor revealed a partially boosting trend in T_{min} level, while none of the station revealed a dramatically raising trend. Therefore, 10% of the stations reported a statistically substantial trend at 5% significance level in the fall. Throughout wintertime, station at Port Pirie revealed a partially enhancing trend while the station at Victor harbor revealed a substantially boosting trend. Therefore, 10% of the stations revealed a statistically considerable trend at 1% as well as 5% significance level. Throughout springtime, stations at Adelaide city, Mount Barker, Port Adelaide, Whyalla, Victor Harbor and also Port Lincoln revealed a considerably boosting trend, leading to 60% of the stations with a statistically significant trend at 1% significance level. In the yearly pattern, stations at Adelaide city, Mount Barker, Port Adelaide, Port Augusta, Whyalla, Port Pirie Victor Harbor and also Port Lincoln revealed a dramatically raising pattern. Therefore, 80% of the stations revealed a significant trend each year at 1% significance level. The stations revealed raising trend in T_{min} level at significance level of 1% and also 5%

Table 4. Statistical test results for the seasonal and annual T_{min} for the period 1981-2016.

Station	Test	Trends				
		Summer	Autumn	Winter	Spring	Annual
Adelaide	Z	2.36*	1.32	1.74	2.96**	3.20**
	Q_{med}	0.033*	0.017	0.07	0.025**	0.022**
Mount Barker	Z	2.30*	2.15*	1.83	2.59**	3.57**
	Q_{med}	0.03*	0.021*	0.025	0.027**	0.029**
Mount Gambier	Z	2.32*	0.00	0.82	0.89	1.54
	Q_{med}	0.026*	0.008	0.003	0.011	0.014
Murray Bridge	Z	2.23*	0.45	0.26	1.21	1.93
	Q_{med}	0.027*	0.008	0.003	0.011	0.014
Port Adelaide	Z	2.94**	1.24	1.24	3.07**	3.81**
	Q_{med}	0.041**	0.015	0.011	0.025**	0.026**
Port Pirie	Z	1.62	1.76	2.43*	1.84	3.09**
	Q_{med}	0.026	0.022	0.028*	0.026	0.023**
Port Augusta	Z	3.19**	1.72	1.46	1.36	3.06**
	Q_{med}	0.059**	0.035	0.018	0.022	0.029**
Whyalla	Z	3.12**	1.27	1.83	4.06**	4.11**
	Q_{med}	0.053**	0.022	0.02	0.067**	0.038**
Victor Harbor	Z	2.49*	1.98	3.64**	3.28**	4.14**
	Q_{med}	0.024*	0.02	0.027**	0.03**	0.025**
Port Lincoln	Z	2.86**	0.95	1.2	2.77**	3.16**
	Q_{med}	0.031**	0.011	0.015	0.026**	0.019**

Z:Mann-Kendall test, Q_{med}: Sen's slope estimator; *Statistically significant trends at the 5% significance level; ** Statistically significant trends at the 1% significance level.

in the summer season, fall, wintertime, springtime and also each year was shown in figures 3a and 3b. Therefore, 40% of the stations in summer season, 10% of the stations in autumn, 10% of the stations in wintertime, and 60% stations in springtime revealed an enhancing trend in T_{min} level. Consequently, the T_{min} level revealed a raising trend in the Adelaide city other than throughout autumn as well as wintertime. Additionally, this remains in conformity with 80% of the stations revealed a raising pattern in Tmin level in the city throughout 1981-2016.

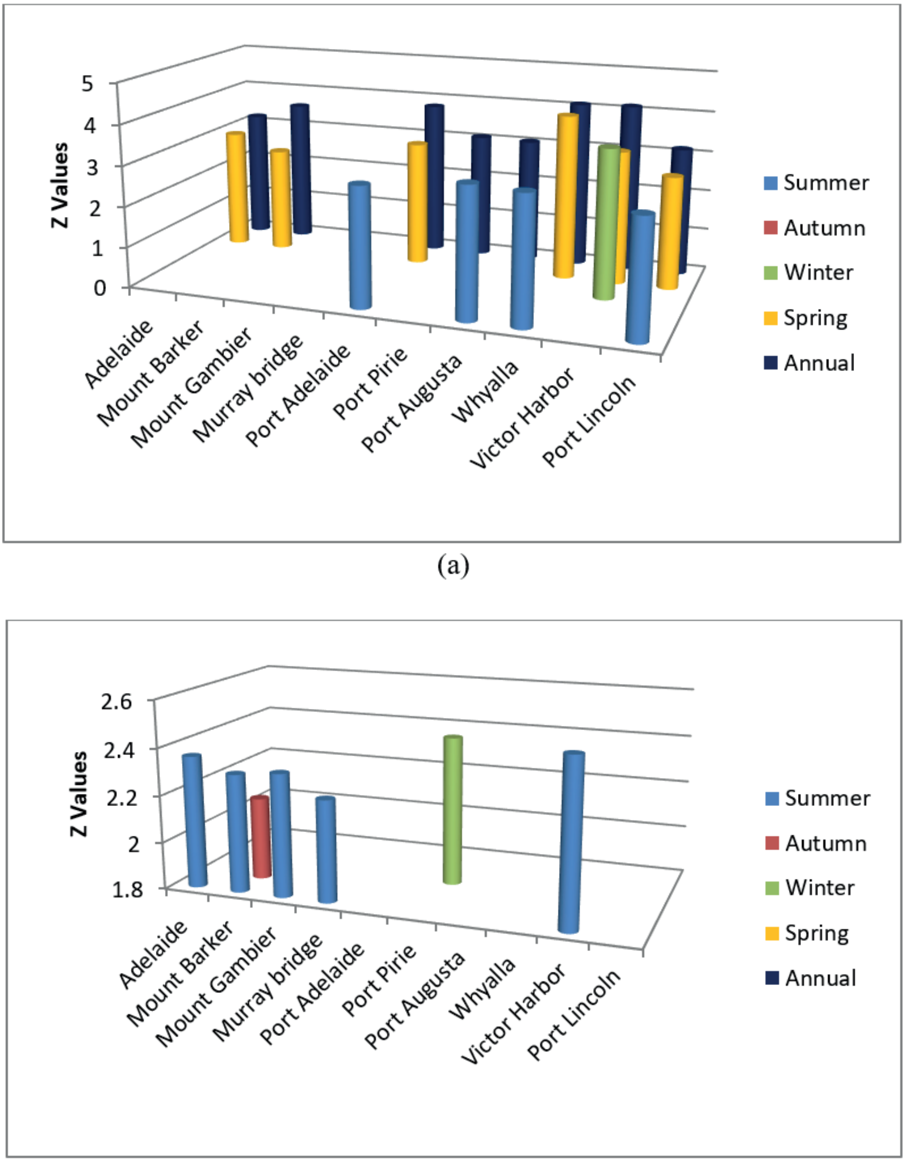


Figure 3. Stations showing increasing trend in T_{min} at significance levels of (a) 1% and (b) 5% in the summer, autumn, winter, spring and annual seasons.

The outcomes obtained for T_{max} and T_{min} remain in conformity with the outcomes by The Commonwealth Scientific and Industrial Research Organization (CSIRO) in 2015 and 2016 which reported that the average temperature level continues to boost up in all periods. Additionally, enhancing patterns, especially in springtime, was reported which supports with our existing research where 60% of the stations revealed an enhancing trend for T_{min} as well as 80% of the stations reveal an enhancing pattern for T_{max} (with 1% significance level). The reason for such observance can be associated to worldwide warming as a result of human impact (CSIRO 2015). Australian population has actually increased from 10.7 million in 2001 to 12.8 million in 2016 as the socioeconomic benefits have actually brought in individuals to this city from rural. Moreover, quick urbanization has actually created noticeable temperature level distinction in between the metropolitan and also rural areas, which is frequently referred to as urban heat island impact.

Table 5 revealed the outcomes of the statistical tests for the seasonal as well as yearly rainfall (R) through 1981-2016. It was observed from Table 5 that throughout summertime, just stations at Port Pirie and also Whyalla revealed a substantial rise in the rain pattern. In fall, just Port Lincoln revealed a partially enhancing trend in rains. None of the stations reveal an enhancing or lowering pattern in rains in the winter season, springtime and also yearly periods. Therefore, just 10% of the stations revealed a raising pattern with 1% significance level in the summertime and also 10% of the stations revealed a boosting trend with 5% significance level in the fall. The stations revealed enhancing pattern in rains at significance levels of 1% and also 5% in the summertime, fall, wintertime, springtime and also yearly periods was displayed in

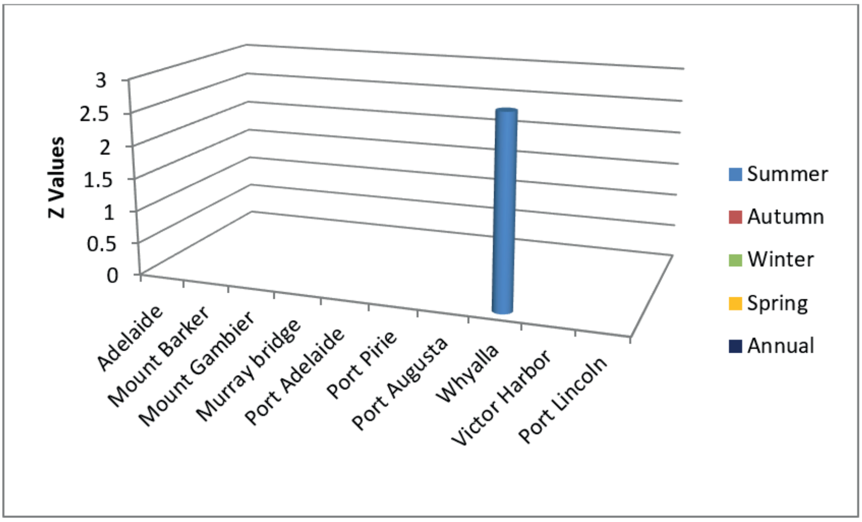
Table 5. Statistical test results for the seasonal and annual R for the period 1981-2016.

Station	Test	Trends				
		Summer	Autumn	Winter	Spring	Annual
Adelaide	Z	1.81	-0.45	-0.86	-0.99	-0.97
	Q_{med}	0.28	-0.076	-0.29	-0.305	-0.106
Mount Barker	Z	1.95	0.07	0.67	0.29	0.64
	Q_{med}	0.297	0.022	0.337	0.117	0.126
Mount Gambier	Z	1.57	0.29	0.42	-0.22	0.53
	Q_{med}	0.31	0.099	0.231	-0.056	0.09
Murray Bridge	Z	1.93	0.59	-0.53	-0.29	0.53
	Q_{med}	0.324	0.121	-0.191	-0.084	0.04
Port Adelaide	Z	1.10	0.07	-0.49	-0.94	-0.72
	Q_{med}	0.167	0.023	-0.154	-0.2	-0.101
Port Pirie	Z	2.49*	1.1	-0.56	-0.37	1.25
	Q_{med}	0.431*	0.288	-0.111	-0.088	0.103
Port Augusta	Z	1.88	1.06	-0.99	-0.34	0.67
	Q_{med}	0.363	0.252	-0.212	-0.078	0.064
Whyalla	Z	2.86**	1.06	-1.21	-1.38	0.31
	Q_{med}	0.488**	0.297	-0.324	-0.294	0.031
Victor Harbor	Z	1.09	-0.49	-0.4	0.18	-0.64
	Q_{med}	0.215	-0.214	-0.295	0.054	-0.126
Port Lincoln	Z	1.01	2.38*	-0.2	0.61	1.29
	Q_{med}	0.174	0.278*	-0.039	0.076	0.152

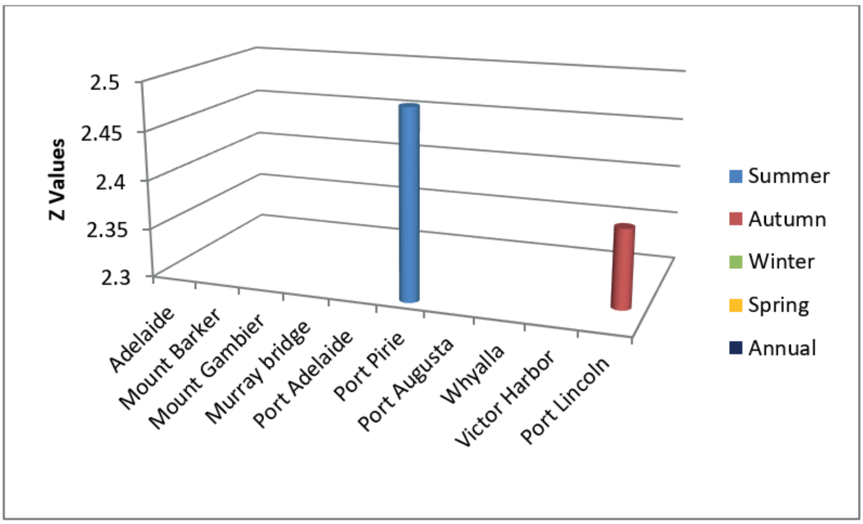
Z:Mann-Kendall test, Q_{med}: Sen's slope estimator; *Statistically significant trends at the 5% significance level; ** Statistically significant trends at the 1% significance level.

figure 4a and 4b. Hence, rising in rains trends was insignificant as well as this remains in close corroboration of our earlier statement that urbanization has actually caused climate change. The anthropogenic heat generation, customized wind pattern as well as raised air contamination has actually influenced the rains pattern in the city of Adelaide.

Table 6 summarized the outcomes of the statistical tests for the seasonal and also yearly solar radiation (S) through 1991-2016. It was observed from Table 6 that there was no substantial enhancing or reducing trend in any one of the stations situated around Adelaide in the summer season through 1991-2016. Throughout fall, the stations at Port Augusta as well as Port Lincoln reveals considerably lowering trend while the station at Whyalla revealed partially reducing trend in solar radiation. It is interesting to note that a considerably reducing pattern has actually been observed for the very first time in the atmospheric observations taped throughout the duration of 1991-2016. Throughout winter season, just the station at Port Pirie revealed partially boosting pattern in solar radiation. Throughout springtime, stations at Adelaide city as well as Port Adelaide revealed



(a)



(b)

Figure 4. Stations showing increasing trend in rainfall at significance levels of 1% and 5% in the summer, autumn, winter, spring and annual seasons.

dramatically boosting pattern in the solar radiation. In the yearly period, just the station situated at Port Adelaide showed partially raising pattern in solar radiation. Therefore, 30% of the stations revealed a lowering trend in the fall. Additionally, 10% of the stations revealed a raising trend at 5% significance level in the winter season and also yearly period, while 20% of the stations revealed a raising pattern in the springtime. Hence, an insignificantly enhancing pattern had actually been observed. It is popularly known that urbanization triggers high discharge of carbon dioxide into the environment which prevents the incoming solar radiation right into the city and also hence a minimal raising trend is noted. The stations revealing raising and falling trend in solar radiation at significance levels of 1% as well as 5% in the summertime, fall, wintertime, springtime and also every year was shown in figures 5a and 5b.

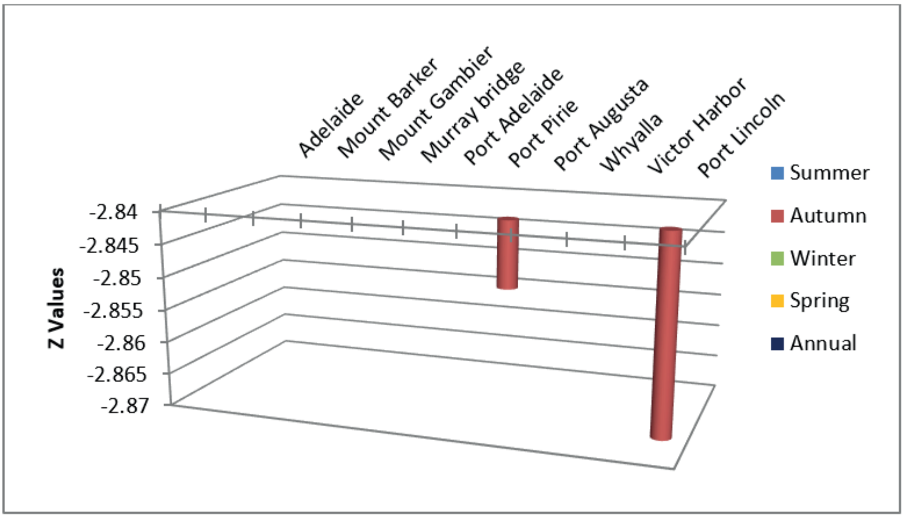
Table 6 summarized the outcomes of the statistical tests for the seasonal and also yearly solar radiation (S) through 1991-2016. It was observed from Table 6 that there was no substantial enhancing or reducing trend in any one of the stations situated around Adelaide in the summer season through 1991-2016. Throughout fall, the stations at Port Augusta as well as Port Lincoln reveals considerably lowering trend while the station at Whyalla revealed partially reducing trend in solar radiation. It is interesting to note that a considerably reducing pattern has actually been observed for the very first time in the atmospheric observations taped throughout the duration of 1991-2016. Throughout winter season, just the station at Port Pirie revealed partially boosting pattern in solar radiation. Throughout springtime, stations at Adelaide city as well as Port Adelaide

Table 6. Statistical test resuls for the seasonal and annual S for the period 1991-2016.

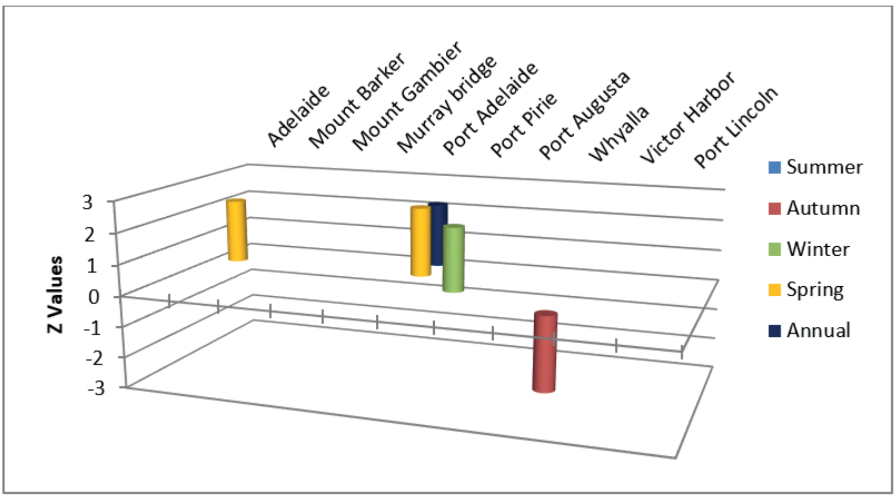
Station	Test	Trends				
		Summer	Autumn	Winter	Spring	Annual
Adelaide	Z	-0.13	-.004	1.23	2.12*	1.19
	Q_{med}	-0.006	0.00	0.026	0.055*	0.024
Mount Barker	Z	-1.59	-1.52	-0.24	0.04	-1.15
	Q_{med}	-0.04	-0.032	-0.003	0.003	-0.019
Mount Gambier	Z	-0.18	-1.52	-0.33	0.11	-0.99
	Q_{med}	-0.007	-0.025	-0.025	0.002	-0.017
Murray Bridge	Z	-1.57	-1.75	0.18	0.00	-0.97
	Q_{med}	-0.042	-0.04	0.003	0.00	-0.025
Port Adelaide	Z	-0.11	1.01	1.13	2.29*	2.12*
	Q_{med}	-0.004	0.022	0.022	0.053*	0.039*
Port Pirie	Z	-0.44	-0.93	2.08*	0.9	0.31
	Q_{med}	-0.013	-0.029	0.031*	0.028	0.01
Port Augusta	Z	-0.97	-2.85**	0.77	0.29	-1.10
	Q_{med}	-0.03	-0.073**	0.01	0.005	-0.021
Whyalla	Z	-1.1	-2.38*	0.9	-0.04	-1.45
	Q_{med}	-0.033	-0.057*	0.015	-0.002	-0.025
Victor Harbor	Z	-0.77	-0.84	-0.4	-0.18	-1.52
	Q_{med}	-0.02	-0.055	-0.01	-0.02	-0.024
Port Lincoln	Z	-0.77	-2.87**	-0.46	-0.53	-1.45
	Q_{med}	-0.02	-0.055**	-0.01	-0.02	-0.024

Z:Mann-Kendall test, Q_{med}: Sen's slope estimator; *Statistically significant trends at the 5% significance level; ** Statistically significant trends at the 1% significance level.

revealed dramatically boosting pattern in the solar radiation. In the yearly period, just the station situated at Port Adelaide showed partially raising pattern in solar radiation. Therefore, 30% of the stations revealed a lowering trend in the fall. Additionally, 10% of the stations revealed a raising trend at 5% significance level in the winter season and also yearly period, while 20% of the stations revealed a raising pattern in the springtime. Hence, an insignificantly enhancing pattern had actually been observed. It is popularly known that urbanization triggers high discharge of carbon dioxide into the environment which prevents the incoming solar radiation right into the city and also hence a minimal raising trend is noted. The stations revealing raising and falling trend in solar radiation at significance levels of 1% as well as 5% in the summertime, fall, wintertime, springtime and also every year was shown in figures 5a and 5b.



(a)



(b)

Figure 5. Stations showing increasing and decreasing trend in solar radiation at significance levels of (a) 1% and (b) 5% in the summer, autumn, winter, spring and annual seasons.

4. Conclusions

The primary objective of this research study is to evaluate the seasonal and also yearly patterns of 4 atmospheric variables in the Adelaide city throughout 1981-2016. The atmospheric data was collected for 10 stations positioned around Adelaide city. The statistical analysis was executed utilizing the non-parameteric Mann-Kendall and also Sen's slope estimator techniques.

The conclusions had been drawn from this research study had actually been summed up as follows;

The outcomes showed that there was a considerably boosting trend in T_{max} in 4 stations in the summertime, 1 station in winter season, 8 stations in the springtime as well as 7 stations in the yearly period. Amongst those stations, those situated in Adelaide city, Mount Gambier, Murray Bridge as well as Port Lincoln reveal raising patterns in T_{max} level throughout summer season, springtime as well as yearly periods. For T_{min}, 4 stations in the summertime, 1 station in the wintertime, 6 stations in springtime as well as 8 stations in the yearly periods revealed a substantially raising trend in T_{min}. Amongst those, stations located at Murray Bridge, Whyalla and also Victor Harbor revealed enhancing pattern in T_{min} in summer season, springtime as well as yearly periods.

There was neither enhancing pattern nor a lowering trend in the rainfall throughout the wintertime, springtime and also yearly periods. Just 10% of the stations (with 1% significance level) as well as 10% of the stations (with 5% significance level) showed a raising pattern in the summer season, while 10% of the stations with 5% significance level revealed a raising pattern in the fall. For solar radiation, 20% of the stations (with 1% significance level) as well as 10% of the stations (with 5% significance level) revealed a substantially lowering pattern in the fall. Throughout winter months and also yearly periods, 10% of the stations revealed a raising trend (with 5% significance level), and also 20% of the stations revealed a raising trend in the springtime (with 5% significance level). In recap, substantially enhancing trends had actually been observed for T_{min} and T_{max} in Adelaide. The rainfall observation throughout the duration of 1981-2016 revealed an insignificantly raising pattern in the summertime and also fall. There is a substantially reducing trend in the solar radiation just throughout the fall period, while majority of the trends in the other seasons have not shown any significant variation. The variant in the trend of the atmospheric criteria evaluated in this research can be credited to climate change in Adelaide city triggered by boosting population as well as fast urbanization.

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