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Evolution of Weather Parameters and Trend Analysis over Junagadh, Gujarat

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ABSTRACT

Climate change is one of the most important worldwide issues talked among the scientists and researchers. The temperature and rainfall trends are analyzed for meteorological data of Junagadh station in Gujarat. India over approximately last three decades stretching between years 1971 to 2013. The long–term change in temperature and rainfall has been assessed by linear trend analysis. The increasing trend in mean monthly maximum temperature (MMAX) and total mean rainfall (TMRF) is confirmed by Mann-Kendall trend test. It is evident from that monthly mean temperature have increased significantly for all the months except the months of April and October for which a very weak decrease in mean maximum temperature is observed. This implies that at Junagadh, the highest increase in temperature occurred in November (0.021^{0}C) during 1980-2011 period. The annual mean of monthly maximum temperatures (MMAX) observed an increasing trend having an annual decreasing of 0.004^{0}C year during 1980-2011. It is evident TMRF have increased for the months April, May August and September whereas it shows decreasing trend in January, Feb, March, June, July, October, November and December. This implies that at Junagadh, the highest increase in TMRF occurs in August and increased by (0.029 mm) during the last 1980-2011. The highest decrease in TMRF occurs in June and decreased by (2.153mm) during the same period. The annual mean of total monthly rainfall observed a decreasing trend having an decrease of 0.249 mm/year during the last 31 years.

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INTRODUCTION

Climate change has brought in unexpected changes not only in India but all over the regions across the world. Emergence of global warming due to climate change is the new and most talked subject of today's world as it being the most threatening issue for very existence of life on the earth. One of the consequences of climate change is the alteration of rainfall patterns and increase in temperature (Deshmukh and Lunge, 2013). According to Intergovernmental Panel on Climate Change (IPCC, 2007) reports, the surface temperature of the earth has risen by 0.6+ 0.2ºC over the 20th century. Also in the last 50 years, the rise in temperature has been 0.13 + 0.07ºC per decade.

As the warming depends on emissions of GHGs in the atmosphere, the IPCC has projected a warming of about 0.2^{0}C per decade. Further, surface air temperature could rise by between 1.1^{0}C to 6.4^{0}C over 21st century. In case of India, the climate change expected to adversely affect its natural resources, forestry, agriculture, and change in precipitation, temperature, monsoon timing and extreme events (Fulekar and Kale, 2010). Due to global warming, precipitation amount, type and timing are changing or are expected to change because of increased evaporation, especially in the tropics (Ritter, 2006).

The pattern and amount of rainfall are among the most important factors that affects agricultural production. Agriculture is vital to India's economy and the livelihood of its people. Agriculture is contributing 21% to the country's GDP, accounting for 115 of total export, employing 56.4% of the total workforce, and supporting 600 million people directly and indirectly (Shah, 2010). Trend analysis of rainfall in different spatial scales will lead to a better understanding of the problems associated with floods, droughts, and the availability of water for various uses with respect to future climate scenarios. Air temperature is also considered a good indication of the state of climate because of its ability to represent the energy exchange process over the earth's surface with reasonable accuracy (Thapliyal and Kulshrestha, 1991).

Indian subcontinent and several investigators have concluded that the trend and magnitude of warming over India/Indian subcontinent over the past century is broadly consistent with the global trend and magnitude (Dash *et al*, 2007). However, the decadal trends over India are quite different from those observed over other parts of the globe because of the comparatively large increase in Tmax over a major part of India (Kumar *et al*, 1994).

Several studies relating to changing pattern of rainfall over India observed that there is no clear trend of increase

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or decrease in average rainfall over the country (Kumar *et al*, 2010). Although long-term trends in monsoon rainfall have not been observed on an all-India scale, several studies have found significant trends in rainfall on a regional scale (Koteswaram and Alvi, 1969; Jagannathan and Parthasarathy, 1973; Pant and Kumar, 1974; Chaudhary and Abhyankar, 1979; Kumar *et al*, 2005; Dash *et al*, 2007; Kumar *et al*, 2010) .

Some studies have shown that, in general, the frequency of intense rainfall events in many parts of Asia has decreased, while the number of rainy days and total annual precipitation has decreased (Dash *et al*, 2007). In India, the climate change is expected to adversely cause changes in precipitation, temperature, monsoon timing and extreme events (Fulekar and Kale, 2010). Due to global warming, precipitation amount, type and timing are changing or are expected to change because of increased evaporation, especially in the tropics (Ritter, 2006). The pattern and amount of the rainfall are among the most important factors that affect agriculture production. Agriculture is vital to India's economy and livelihood of its people. Agriculture is contributing 21% to the country's GDP, employing 56.4% of the total workforce and supporting 600 million people directly and indirectly (Shah, 2010). In India despite recent progress in industrlization, the soundness of economy is significantly dependent upon the gross production of agricultural commodities and agriculture is the mainstay of millions of teeming population with crops predominantly dependent upon naturalrainfall. Excepting the south-eastern part of the peninsula and Jammu and Kashmir, the south west monsoon (June – Sept.) is the principle source of rain in the entire country. During monsoonal period more than 75% of annual rainfall is received over a major portion of the country. India's economy has traditionally been agricultural in nature and excess climate anomalies, deficient and flooded rainfall years have a dramatic impact on the economy as well as on the living conditions of the inhabitants of the affected regions (Parthasarthy *et al*, 1988). The green revolution on technology has increased the rice and other food grain production and productivity substantially.

MATERIALS AND METHODS

The Junagadh city is located between latitudes 21º 31'N and 70º 49' E (Figure 1). Junagadh has a tropical wet and dry climate, with three distinct seasons observed, a mild winter from November to February, a hot summer from March to June, and a monsoon from July to October. Junagadh faces adverse climatic conditions in the summer months with the temperature ranging from 28° C to 38°C. In the winter months, the temperature ranges from 10°C to 25°C. Various factors such as its close proximity to the sea influence the weather of Junagadh. The latent winds from the sea affect the climatic conditions in the region.

Fig. 1: Location map of study area of Junagadh

The monthly rainfall, mean monthly maximum temperature data during 1980-2011 for (31 years) have been collected for the Dept of Agrometeorology, JAU, Junagadh. The yearly averages were calculated from the monthly readings which are analyzed. Trend is defined as the general movement of a series over an extended period of time or it is the long term change in the dependent variable over a long period of time (Webber and Hawkins, 1980). Trend is determined by the relationship between the two variables as temperature and time, rainfall and time. The statistical method such as regression analysis and coefficient of determination R^2 are used for the significance of trend of temperature and rainfall. The trend were derived and tested by Mann-Kendall (1945) trend test and slope of the regression line using the least squares method. The mean, standard deviation (SD) and coefficient of variation (CV) of rainfall and temperatures have been calculated to analyses (Khavse *et al*, 2015). The statistical significance of trends in monthly rainfall and temperature were examined by Mann-Kendell rank statistics test. The monthly and season-wise trends were also computed through a trend line technique (Chinchorkar *et al*, 2013).

The Mann-Kendall test is a non-parametric test for identifying trends in time series data. The test compares the relative magnitudes of sample data rather than the data values them. One benefit of this test is that the data need not confirm to any particular distribution. Let X1, X2………. Xn represents n data points where Xj represents the data point at time j. Then the Mann-Kendall statistic (S) is given by

$S = \sum\sum$ sign (Xj-Xk), J=2, 3……n; k = 1,2…..j-1

Where

sign (Xj-Xk)= 1 if (Xj-Xk)>0

=0 if Xj-Xk= 0

=-1 if Xj-Xk< 0

A very high positive value of S is an indicator of an increasing trend, and a very low negative value indicates a decreasing trend. However, it is necessary to compute the probability associated with S and the sample size, n, to statistically quantify the significance of the trend. For a sample size >10, a normal approximations to the Mann-Kendall test may be used. For this, variance of S is obtained as,

$V(s) = [n(n-1)(2n+5)-\sum tp(tp-1)(2tp+5)]/18$, p=1,2……p

Where tp is the number of tiles for pth value and q is the number of tied values.

The standardized statistical test is

$Z= S-1/\sqrt{V(S)}$ if S>0,

=0 if S=0,

$= S+1/\sqrt{V(s)}$ if S<0

The presence of a statistically significant trend is evaluated using Z value.

RESULTS AND DISCUSSION

Monthly and Annual TMax (TMAX)

The trends of monthly mean maximum temperature over different years were obtained using linear regression best fit lines. The linear regression trends with their linear regression equations and coefficient of determination for all the months from January to December are represented in Figure 2 and summarized in Table 1. It is evident from figures that monthly mean temperature have increased significantly for all the months except the months of April and October for which a very weak decrease in mean maximum temperature is observed. This implies that at Junagadh station district the highest increase in temperature occurred in November (0.021^0C) during 1980-2011 period.

Annual Mean of monthly maximum Temperature (MMAX)

The annual mean of monthly maximum Temperatures (MMAX) observed an increasing trend having an annual decreasing of 0.004^0C per year, as represented in Figure 3during 1980-2011. The statistical summary of maximum temperature for all months is finalized in Table 1. Coefficient of variation for mean temperature for Junagadh station is highest in the month of January and it is observed as 6.29% whereas it is lowest in the month of April and it is 2.96%. This means that mean temperature is most stable in the month of April and least stable in the month of January for the Junagadh district. The coefficient of variation for TMRF observed highest in the month of April and it is 529 % whereas coefficient of variation is minimum for the month of July and it is 63 % for the Junagadh station. This shows that rainfall is more stable in the month of July and is more variable in the month of April.

Total Monthly rainfall (TMRF)

The trends of total mean rainfall over different years were obtained using linear regression best fit lines. The linear regression trends with their linear regression equations and coefficient of determinations for all the months from January to December are represented in Figure 4and summarized in Table 2. It is evident that TMRF have increased for the months April, May August and September whereas it shows decreasing trend in January, Feb, March, June, July, October, November and December. This implies that at Junagadh station the highest increase in TMRF occurs in August and has increased by (0.029 mm) during the last 1980-2011. The highest decrease in TMRF occurs in June and decreased by (2.153mm) during the same period.

Table 1: Statistical summary and Linear regression equations of monthly mean temperatures (MMAX)

Month	**Mean**	**SD**	**CV (%)**	**Regression line**	**R^2**
January	29.70	1.87	6.29	y = 0.008x + 29.55	R^2 = 0.001
February	31.85	1.93	6.06	y = 0.004x + 31.78	R^2 = 0.0001
March	36.10	1.43	3.96	y = 0.035x + 35.51	R^2 = 0.052**
April	39.13	1.16	2.96	y = 0.037x + 38.51	R^2 = 0.092
May	38.81	1.18	3.04	y = -0.034x + 39.37	R^2 = 0.073
June	35.62	1.15	3.22	y = 0.01x + 35.45	R^2 = 0.006
July	31.71	1.21	3.83	y = -0.023x + 32.10	R^2 = 0.034
August	30.48	1.10	3.60	y = -0.015x + 30.73	R^2 = 0.016
September	32.72	1.25	3.82	y = -0.045x + 33.46	R^2 = 0.116
October	35.77	1.41	3.96	y = -0.025x + 36.2	R^2 = 0.029
November	34.10	1.14	3.35	y = 0.021x + 33.74	R^2 = 0.030
December	31.15	1.21	3.90	y = -0.021x + 31.51	R^2 = 0.027

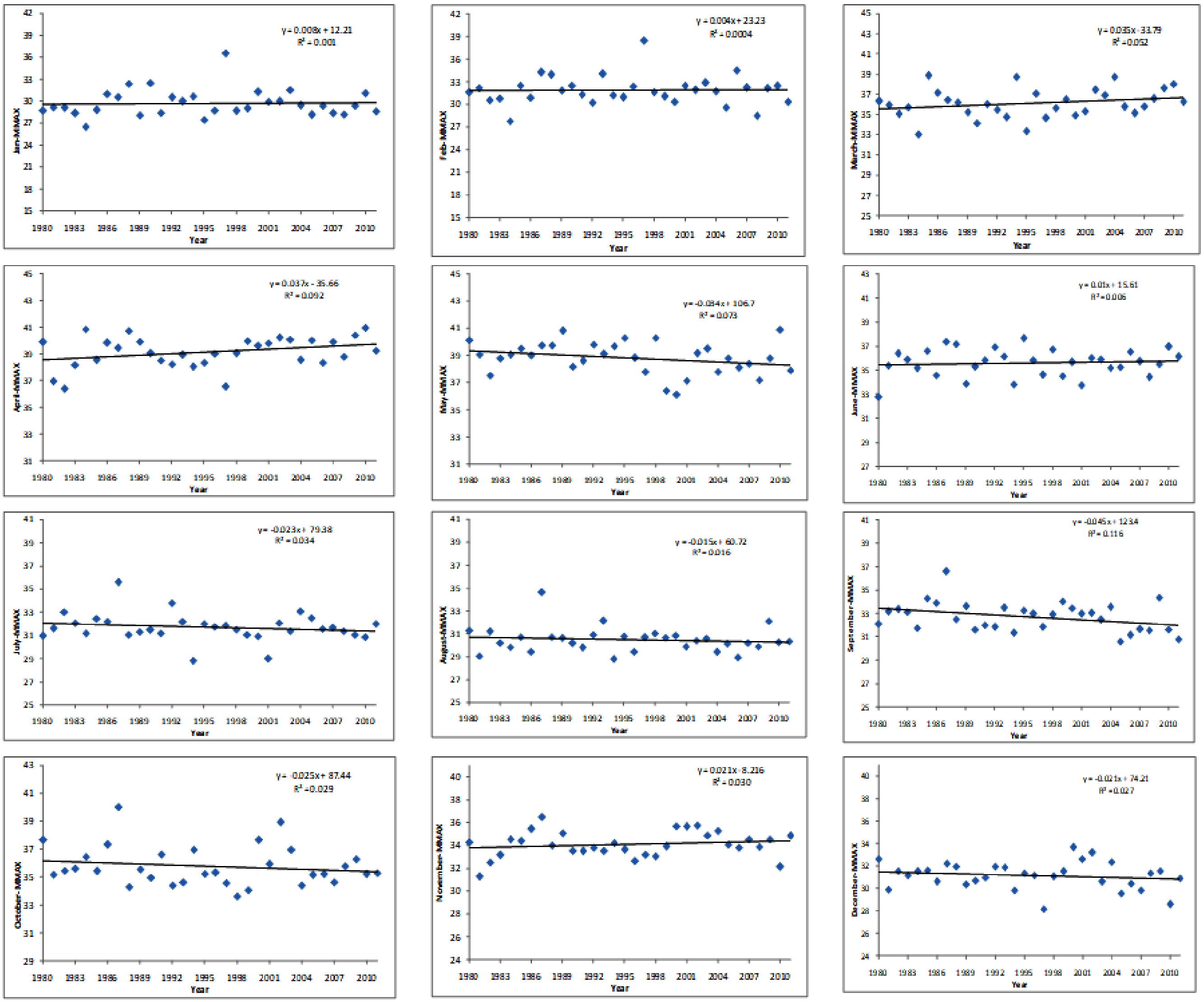

Fig. 2: Trend of monthly mean of maximum temperature during1980 to 2010

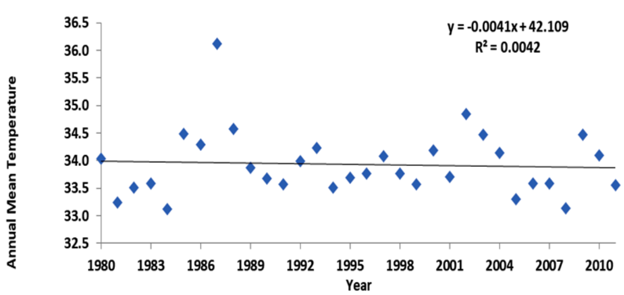

Fig. 3: Trend of annual mean of monthly mean temperatures

Annual Mean of total monthly rainfall (TMRF)

From the Figure 4, the annual mean of monthly mean of total mean rainfall observed a decreasing trend having an increase of 0.3249 mm per year. This implies that in Junagadh annual TMRF has increased during the last 31 years

CONCLUSION

It is observed that the monthly mean temperature have increased significantly for all the months except the months of April and October for which a very weak decrease in mean maximum temperature is observed. This implies that at Junagadh station district the highest increase in temperature occurred in November (0.021^{0}C) during 1980-2011 period. The annual mean of monthly maximum Temperatures (MMAX) observed an increasing trend having an annual decreasing of 0.004^{0}C per year during 1980-2011. It is evident TMRF have increased for the months April, May August and September whereas it shows decreasing trend in January, Feb, March, June, July, October, November and December. This implies that at Junagadh station the highest increase in TMRF occurs in August and has increased by (0.029 mm) during the last 1980-2011. The highest decrease in TMRF occurs in June and decreased by (2.153mm) during the same period. The

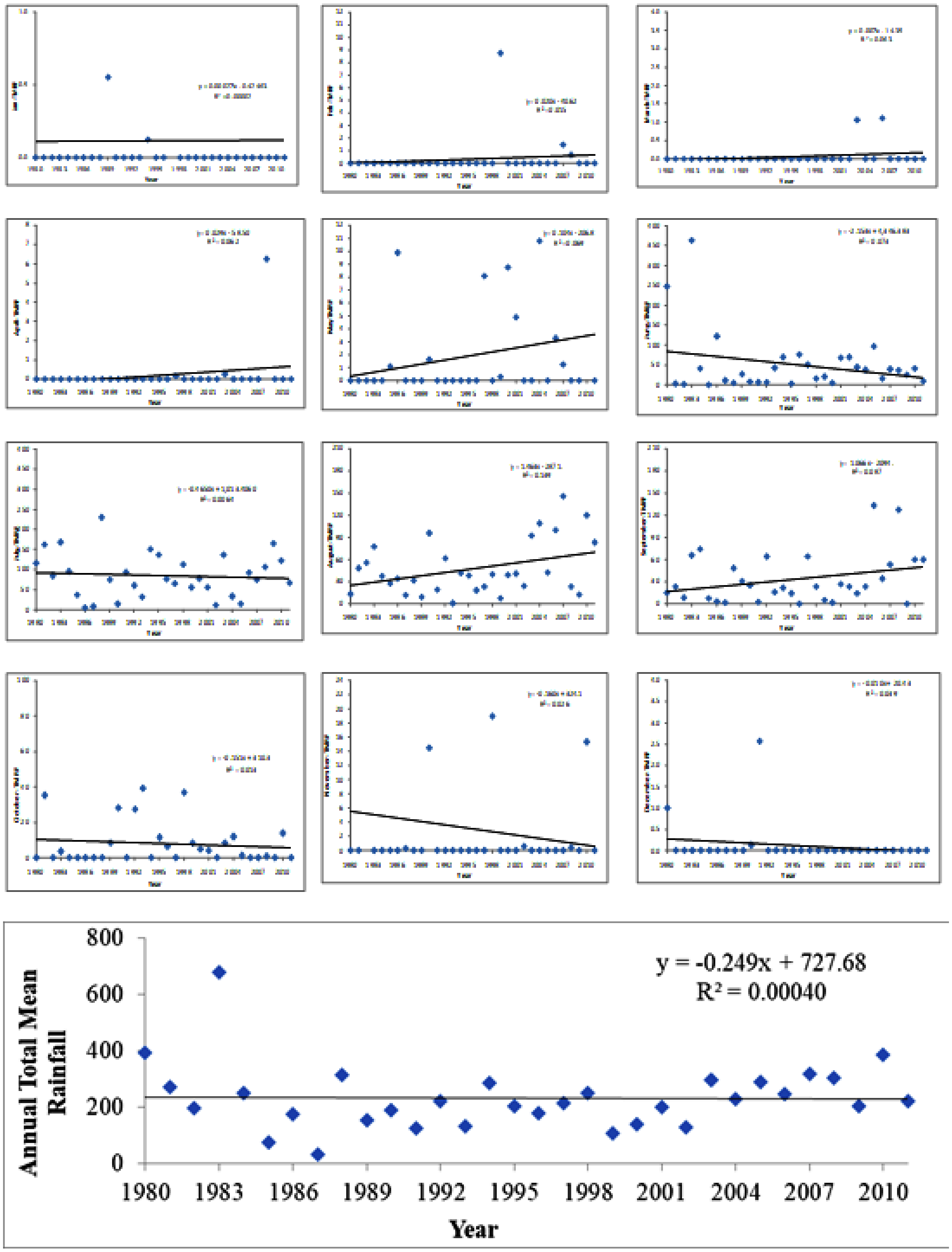

Fig. 4: Linear regression trends of monthly and annual mean of maximum temperatures

Table 2: Statistical summary and Linear regression equations of monthly total mean rainfall (TMRF)

Month	**Mean**	**SD**	**CV (%)**	**Regression line**	**R^2**
January	0.11	0.54	466.46	y = 0.000x + 0.110	R^2 = 2E-05
February	0.34	1.56	458.23	y = 0.020x + 0.001	R^2 = 0.015
March	0.07	0.27	393.65	y = 0.007x - 0.051	R^2 = 0.063
April	0.21	1.10	529.12	y = 0.029x - 0.276	R^2 = 0.062
May	1.95	3.72	190.85	y = 0.104x + 0.223	R^2 = 0.069
June	50.41	74.78	148.33	y = -2.152x + 85.93	R^2 = 0.072
July	85.48	54.68	63.98	y = -0.465x + 93.14	R^2 = 0.006
August	47.78	36.70	76.81	y = 1.463x + 23.64	R^2 = 0.139
September	33.55	33.90	101.03	y = 1.066x + 15.95	R^2 = 0.087
October	7.82	12.10	154.68	y = -0.151x + 10.32	R^2 = 0.013
November	3.03	9.37	308.89	y = -0.160x + 5.688	R^2 = 0.026
December	0.12	0.48	417.34	y = -0.010x + 0.283	R^2 = 0.039

annual mean of total monthly rainfall observed in decreasing trend having a decrease of 0.249 mm per year during the last 31 years. Annual TMRF shows increasing trend which is statistically insignificant at 5% level of significance.

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