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Recent Changes in Crop Water Requirement (Pan-Evaporation) at Anand, Gujarat, India

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ABSTRACT

Climate change scenario badly affects agriculture. The present study aimed to characterize the trend in maximum temperature and crop water requirement over a last decade at Akola station (Maharashtra State), be- cause of changing trend in meteorological parameters. Study investigated the trends in temperature and reference evapotranspiration using various statistical parameters like mean, coefficient of variation, coefficient of skewness and coefficient of kurtosis. There was unsteady variation in monthly maximum temperature. The coefficient of variation ranged between 2.85-4.72 which indicated the variation in maximum air temperature over the year. Monthly maximum air temperature showed linear slightly decreasing trend for the months January to May and December, whereas for months from June to November, it showed an increasing trend. Hence it was concluded that in general there was a slightly decreasing trend in monthly maximum air temperature during summer season while increasing trend over monsoon and winter seasons. It was seen that monthly reference evapotranspiration showed a decreasing linear trend for April, August, September, October, November and December, while increasing trend for February, March and June. However, for January, May and July, monthly reference evapotranspiration showed a somewhat constant linear trend. In general, the monthly reference evapotranspiration showed a decreasing linear trend over the monsoon and winter seasons, whereas an increasing trend over the summer season.

Keywords: Climate change, Evapotranspiration, Moving averages, Temperature, Trend analysis

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INTRODUCTION

The effective use of water both in irrigated and rainfed area for crop production is essential. Adopting the exact or correct amount of water and correct application timimg is essential for scheduling irrigations to meet the crop's water demands and for optimum crop production. Jensen *et al*. (1990) provided detailed reviews of the methods commonly used to determine evapotranspiration and crop water requirements. The irrigation scheduling based on crop water requirement (ETc) determined by multiplying crop coefficient (Kc) values with reference evapotranspiration (ETo), is one of the widely used method (Doorenbos and Pruitt, 1975). Based on availability of weather data, various methods (Blaney-Criddle, 1950; Turc, 1961; Christiansen, 1968; Priestly-Taylor, 1972; Hargreaves-Samani, 1985; FAO Penman-Monteith method: Allen *et al*., 1998) have been suggested. Among all the methods Penman-Monteith method (Allen *et al*., 1998) has been reported to yield consistently more accurate reference evapotranspiration (ETo) estimates across a wide range of climate conditions (Jensen *et al*., 1990; Kashyap and Panda, 2001; Irmak *et al*., 2003). Since Kc values are found to be crop, location and season specific, hence, need to be corrected for each location (Shanker *et al*., 2012; Mehta and Pandey, 2015) to determine ETc.

The rainfall and temperature are the most fundamental physical parameters among the climate as they determine the environmental factors of the particular region which affects the agricultural productivity. The annual mean temperature of India as a whole has risen by 0.51°C over the period 1901-2005 (Fulekar and Kale, 2010). Several scientific research studies shown that surface air temperature increased about 0.2 to 0.6° C during last century (Abaurrea and Cerian, 2001) and further it may increase by about 1.5 to 4.5°C until 2100 (Rajendra, 2004). This rate of increase may vary in different geographical regions.

The global warming affects the local climate differently. Crop water requirement depends on climate, soil. Thus, crop water requirement varies from location to location. Therefore, location specific studies are needed to study the trends in crop water requirements. The present study was carried out with the main objective of investigating the trends in crop water requirement (reference evapotranspiration) along with pan evaporation and temperature for Anand of Gujarat region.

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MATERIALS AND METHODS

Data: Anand is located at latitude 22° 32' N, longitude 72° 59' E and altitude 45.1 m (Fig. 1). Daily meteorological data viz. maximum temperature (Tmax), minimum temperature (Tmin), bright sunshine hours (BSH), wind speed (Ws), morning relative humidity (RH-I), evening relative humidity (RH-II) etc were collected from were obtained from Agromet data bank, Department of Agricultural Meteorology, Anand Agricultural University, Anand for the period of 1980-2011 (31 years).

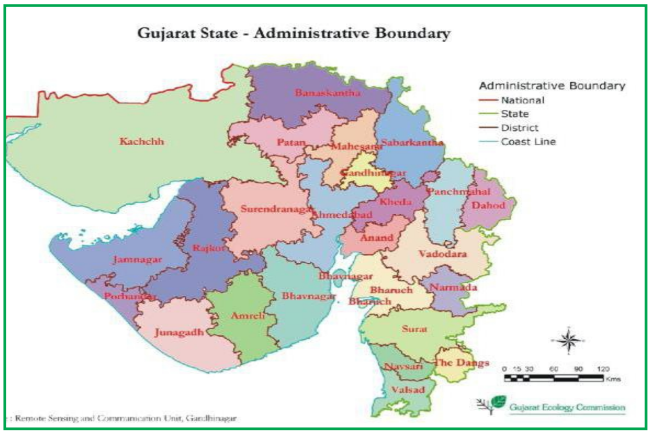


Fig. 1: Location Map of study area

Determination of reference evapotranspiration (ETo):

FAO version of Penman-Monteith model is so accurate that it is recommended as the sole method of calculating ETo if data are available (Allen *et al.*, 1998) and is expressed as:

$$\left[ETo = \frac{0.408\Delta(Rn - G) + \Upsilon \frac{900}{T + 273} u2(es - ea)}{\Delta + \Upsilon(1 + 0.34u2)} \right]$$

where,

ETo = Reference evapotranspiration (mm day-1),

Δ = Slope of saturation vapour pressure curve (kPa ◦C-1),

T = Mean air temperature (◦C),

g = Psychometric constant (kPa ◦C-1)

Rn = Net radiation at the crop surface (MJ m-2 day –1),

G = Soil heat flux density (MJ m-2 day –1),

u2 = Wind speed at 2.0 m height (ms-1),

ea = Actual vapour pressure (kPa),

es = Saturation vapour pressure (kPa),

es- ea= Saturation vapour pressure deficit (kPa).

Statistical tests:

Data of temperature and estimated ETo were analyzed statistically to test its variability, by determining average, standard deviation, coefficient of variation, skewness and kurtosis. These statistical tests are described below in brief.

Average (m):

The average is the average value of the data. It is a measure of *locality*, i.e. the centre of mass of the histogram.

$$\left[m = \frac{1}{n} + \sum_{i=1}^{n} zi \right]$$

Where, n the number data and zi the value of the i^{th} observation.

Standard deviation:

The standard deviation is a measure of spread. It has the same units as the original variable. It is calculated as the square-root of the variance.

$$s_z = \sqrt{s_z^2}$$

$$= \sqrt{\frac{1}{n}\sum_{i=1}^{n}(z_i - m_x)^2}$$

Coefficient of variation:

The coefficient of variation is also measure of spread that is relative to the magnitude of the variable considered. It is calculated as below.

$$CV_z = \frac{s_z}{m_z}$$

This measure only makes sense for variables with strictly positive values.

Skewness:

The skewness of the frequency distribution describes whether it is symmetrical around its central value or whether it is asymmetrical with a longer tail to the left (<0) or to the right (>0). It is calculated using following relationship.

$$CVz = \frac{sz}{mz}$$

This measure only makes sense for variables with strictly positive values.

Skewness:

The skewness of the frequency distribution describes whether it is symmetrical around its central value or whether it is asymmetrical with a longer tail to the left (<0) or to the right (>0). It is calculated using following relationship.

$$CS_z = \frac{\frac{1}{n}\sum_{i=1}^{n}(z_i - m_x)^3}{s_z^3}$$

Kurtosis:

The kurtosis measures the 'peakedness' of the frequency distribution and is calculated from the data as

$$CC_z = \frac{\frac{1}{n}\sum_{i=1}^{n}(z_i - m_z)^4}{s_z^4} - 3$$

The kurtosis compared the peakedness of the distribution with that of a normal distribution. It is either more peaked when larger than zero or flatter when smaller than zero.

Moving average technique:

The trends in temperature and ETo were studied by using moving average tech- nique. The moving average is a weighted mean of previous end data of weather parameter. For 10 month simple moving average of weather parameter is the mean of the previous weather parameters i.e. PM, PM_{-1},

$$\text{Moving average} = \frac{P_M + P_{M-1} + \ldots\ldots + P_{M-9}}{10}$$

PM_{-2},....... PM_{-9} and is given as

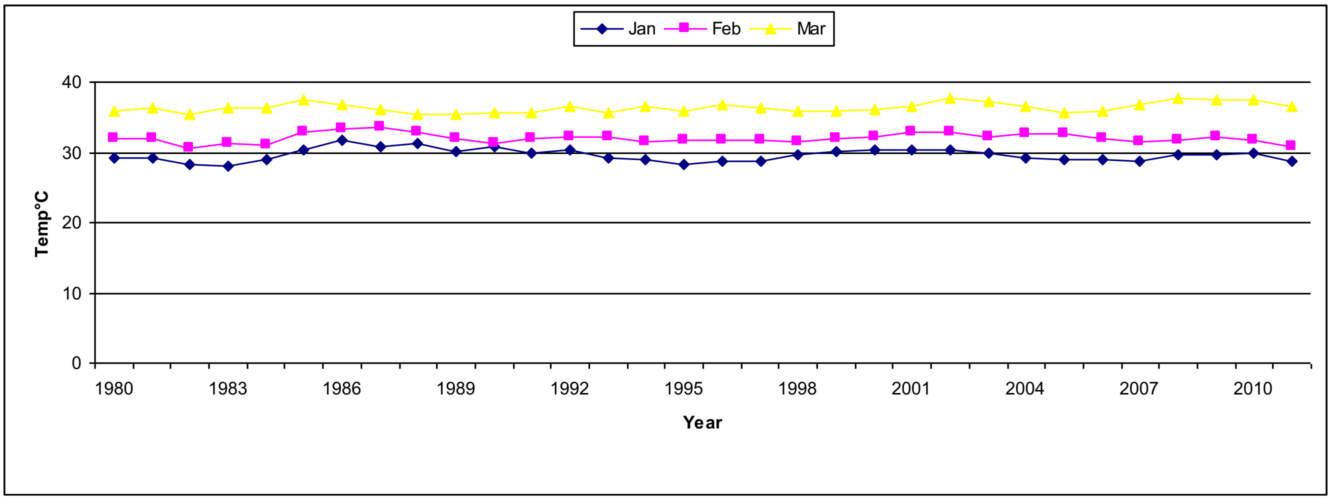
When calculating successive values, a new value comes into the sum and old value drop out, meaning a full summation each time. Three years moving averages were carried out and plotted to check the trends existed in each parameter.

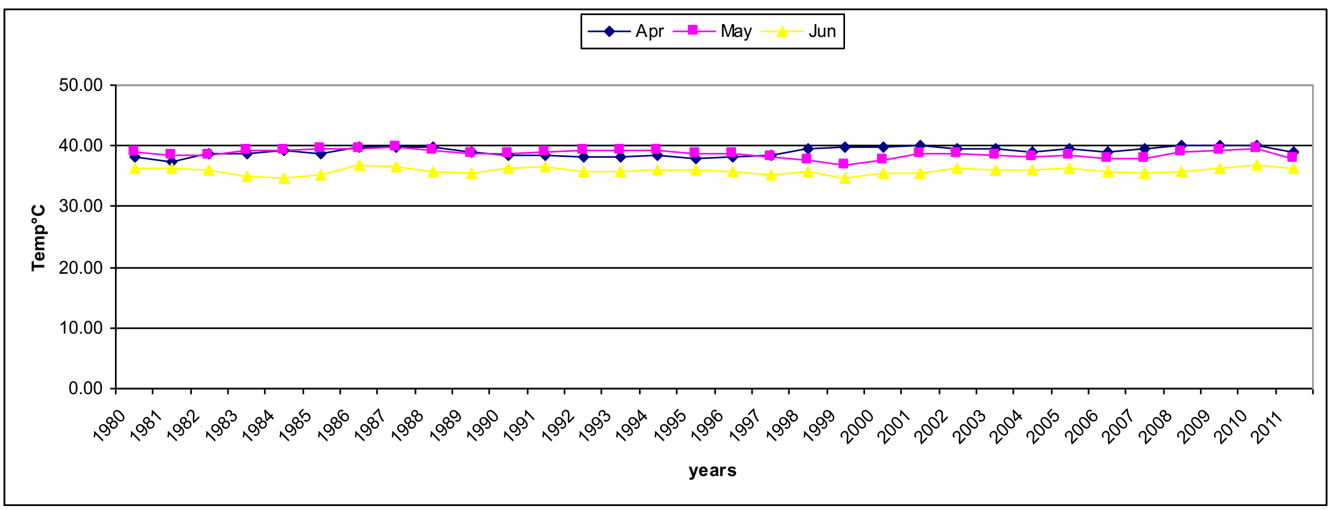
RESULTS AND DISCUSSION

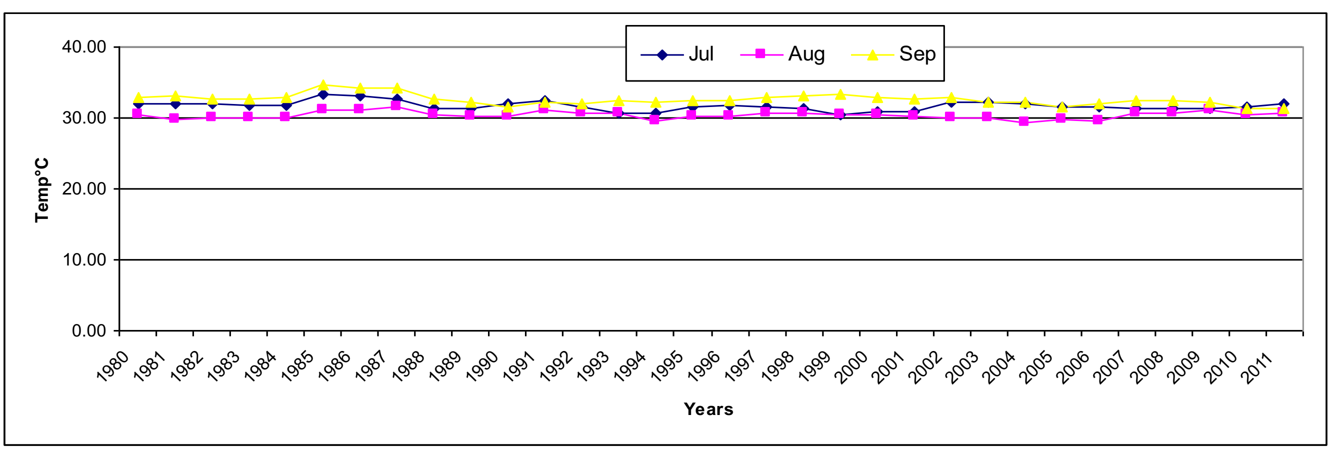
The results of the study are discussed in the following subsections.

Maximum air temperature:

Table 1 presents the statistical characteristics of mean monthly maximum air temperature for 31 years.







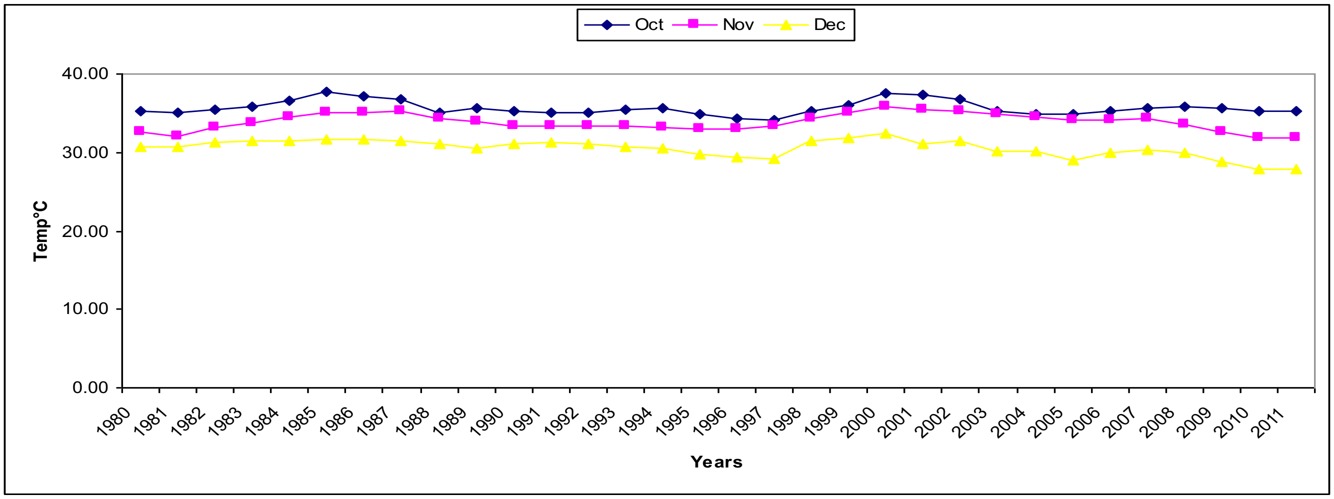


Fig. 2: Three years moving average in mean monthly air temperature

Table 1: Statistical characteristics of mean monthly maximum air temperature

Month	Mean Temp° C	Standard Deviation °C	Coefficient of variation, %	Coefficient of skewness	Coefficient of kurtosis
January	29.61	1.36	4.60	0.37	0.36
February	32.05	1.37	4.26	-0.38	0.61
March	36.34	1.44	3.97	-0.30	0.39
April	39.07	1.25	3.19	-0.44	-0.30
May	38.75	1.10	2.85	-0.28	0.22
June	35.86	1.14	3.19	-0.60	-0.18
July	31.67	1.18	3.71	0.67	5.01
August	30.38	1.09	3.57	1.00	2.02
September	32.63	1.14	3.50	0.99	2.50
October	36.65	1.41	3.95	1.30	2.02
November	33.90	1.22	3.60	-0.01	-0.38
December	30.63	1.45	4.72	-0.72	0.49

It is seen from Table 1 that the mean monthly maximum air temperature varied between 29.61 – 39.07°C. Highest maximum air temperature was found during the month of April, whereas lowest maximum air temperature was found during month of January. The coefficient of variation ranged between 2.85 – 4.72 which indicated the variation in maximum air temperature. Variation did not show any particular pattern either season wise or month wise. Table 1 indicates that the monthly maximum air temperature series is mostly positively skewed, whereas kurtosis was found to be varying between -0.01 to 1.30. Three years moving average trends in mean monthly maximum air temperature is depicted in Fig. 2. It is seen from Fig. 2 that monthly maximum air temperature showed linear slightly decreasing trend for the months of January to May and December, whereas for months from June to November, it showed increasing trend. Hence it was concluded that in general there was slightly decreasing trend in monthly maximum air temperature during summer season

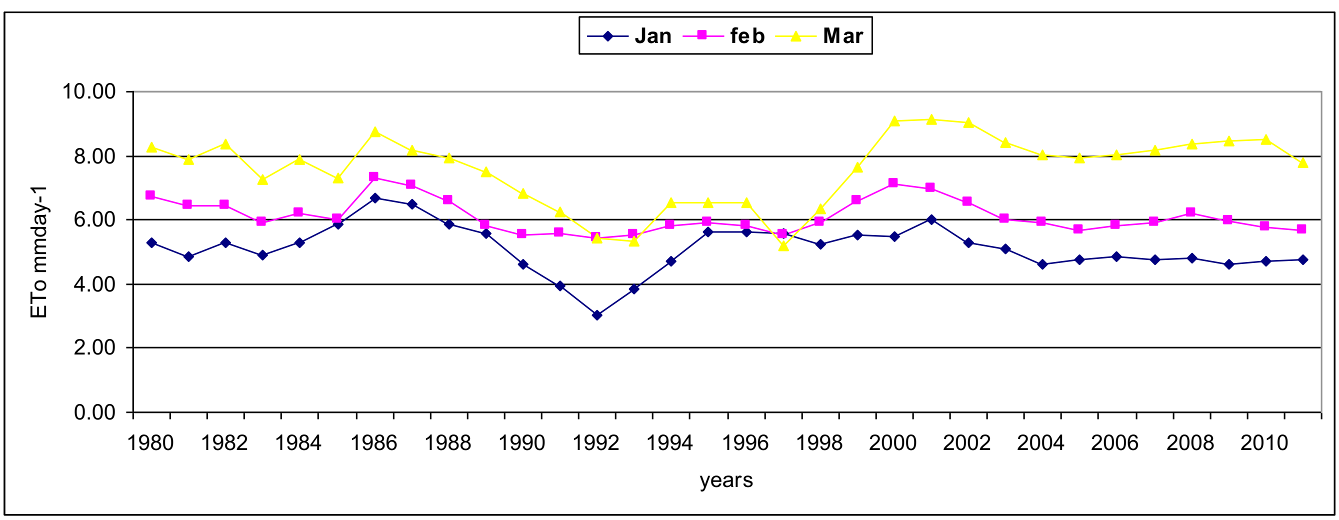
Table 2: Statistical characteristics of mean monthly reference evapotranspiration

Month	Mean $mmday^{-1}$	Standard Deviation °C	Coefficient of variation, %	Coefficient of skewness	Coefficient of kurtosis
January	5.14	1.04	20.19	-0.40	-0.07
February	6.15	0.83	13.55	0.25	0.20
March	7.60	1.52	20.03	-0.70	-0.87
April	8.60	2.19	25.43	-0.71	-1.12
May	8.47	1.98	23.33	-0.75	-0.87
June	6.89	1.35	19.64	-0.33	0.30
July	4.80	1.51	31.57	0.32	-0.71
August	3.74	1.40	37.58	0.29	-0.52
September	4.41	1.23	27.84	-0.11	-0.01
October	5.25	0.98	18.68	1.56	4.01
November	5.13	1.01	19.63	1.09	2.39
December	4.90	0.81	16.52	0.49	1.14

while increasing trend over monsoon and winter season. The results conform with those of Jhajharia and Singh (2011), Jhajharia *et al*. (2014) and Deshmukh *et al*. (2015).

Reference Evapotranspiration

The statistical characteristics of mean monthly reference evapotranspiration for the period of 31 years are presented Table 2. It is seen from Table 2 that the mean monthly reference evapotranspiration varied from 3.74 to 8.60 $mmday^{-1}$. The coefficient of variation ranged between 13.55 to 37.58%, which indicated variations in monthly reference evapotranspiration throughout the year. Table 2 indicated that monthly reference evapotranspiration series mostly positively skewed, whereas kurtosis was found in the range of -0.01 to 4.01. Three years moving average of monthly reference evapotranspiration were estimated and plotted month wise as shown in Fig. 2. It was seen that monthly reference evapotranspiration showed the decreasing linear trend for April, August, September,



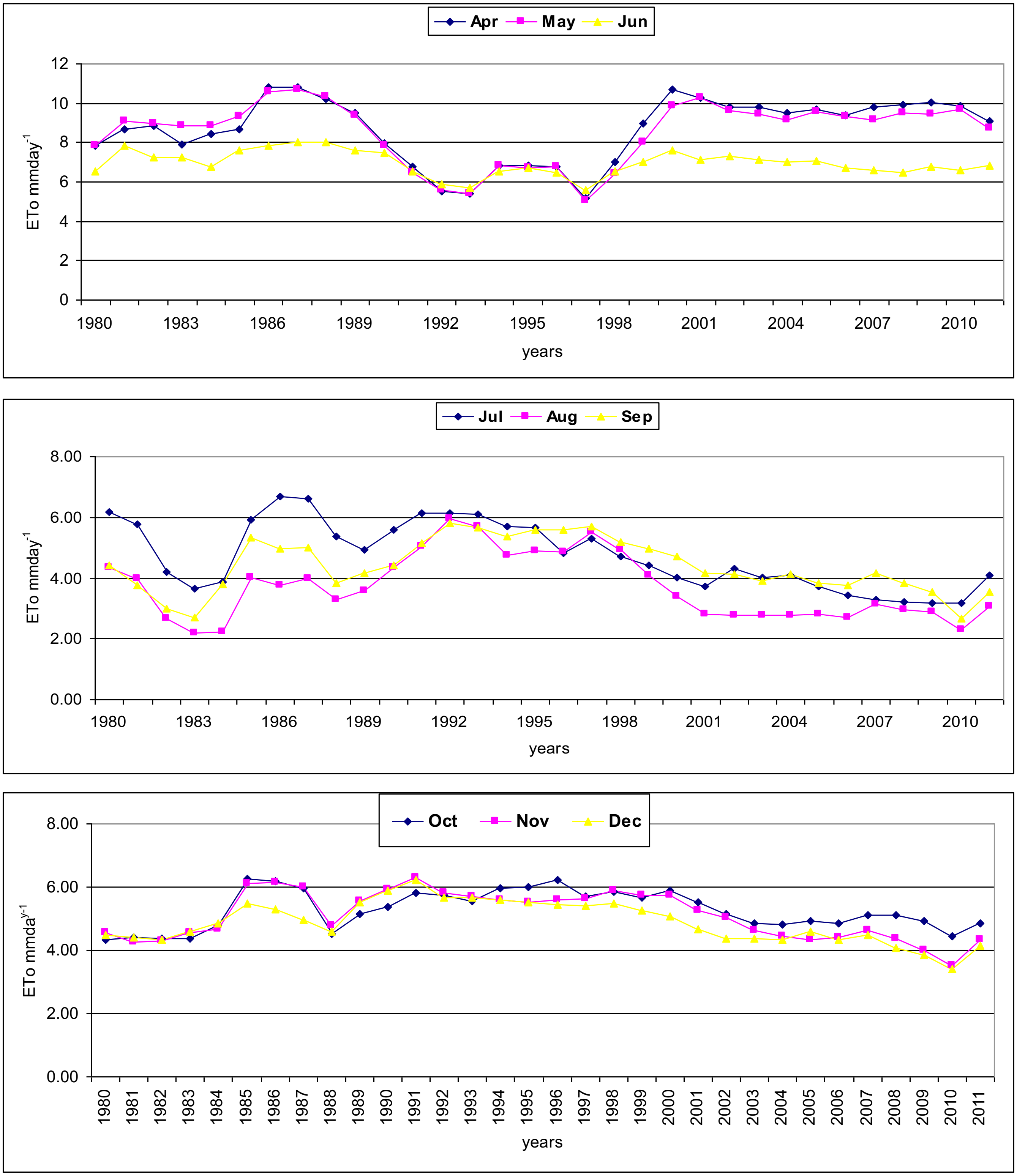


Fig. 3: Three years moving average trends in mean monthly reference evapotranspiration

October, November and December, while increasing trend for February, March and June. However, for January, May and July, monthly reference evapotranspiration showed the somewhat constant linear trend. In general, the monthly reference evapotranspiration showed the decreasing linear trend over monsoon and winter season, whereas increasing trend over summer season. The results are in conformity with those of Jhajharia *et al*. (2014) and Deshmukh *et al*. (2015). As for most of the months of the year, the monthly reference evapotranspiration showed the decreasing linear trend, the crop water requirement at Anand station may decrease in future.

CONCLUSION

From above discussion following findings were drawn

- There was unsteady variation in monthly maximum temperature. The coefficient of variation ranged between 2.85-4.72 which indicated the variation in maximum air temperature over the year.
- Monthly maximum air temperature showed linear slightly decreasing trend for the months January to May and December, whereas for months from June to November, it showed increasing trend. Hence it was concluded that in general there was slightly decreasing trend in monthly maximum air temperature during summer season while an increasing trend over monsoon and winter seasons.
- It was seen that monthly reference evapotranspiration showed the decreasing linear trend for April, August, September, October, November and December, while increasing trend for February, March and June. However, for January, May and July, monthly reference evapotranspiration showed a somewhat constant linear trend. In general, the monthly reference evapotranspiration showed a decreasing linear trend over monsoon and winter season, with increasing trend over the summer season.

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