

Temperature and Precipitation Fluctuation of Madinah-Al-Munawara, Kingdom of Saudi Arabia (1959-2011)

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Abstract

The work discusses the temperature and precipitation fluctuation of Madinah-Al-Munawara, Saudi Arabia for a time period of 1959-2011. This is a city in the Hejaz region of western Saudi Arabia, the capital of Al Madinah Province and important religious place. For many years now, Royal Kingdom of Saudi Arabia is active on national as well as international levels to adopt a more suitable policy for the study of climate changes and reviews it periodically as per country economic desires. The main sectors that affect the temperature and precipitation fluctuations in Saudi Arabia are surface water, coastal management, overgrazing, forestry, livestock, drought, desertification, industrialization, landuse change, tourism, and aridity etc. The paper analyzes the temperature and precipitation fluctuations of Madinah-Al-Munawara in terms of general climatology, climate fluctuation/variation, seasonal distribution and extreme weather events. The mean monthly temperature of the city recorded during 1959-2011 is 28°C having mean maximum temperature of 34°C and mean minimum of 21°C. The mean monthly temperature of the city shows an increase of 1.7°C having 1.2°C increase in maximum temperature and decrease of -1.9°C in minimum temperature. Generally, there is a rise and fall in the temperature condition and shows irregular pattern throughout the period. The total precipitation of the city is 36 millimeters; having a decrease of -0.3 millimeters but in general the trend of precipitation at Madinah-Al-Munawara shows an increasing trend throughout the period. April and November are the wettest, while June, August, September and October are the hottest months of the city. The area is characterized by two main seasons that is winter (5 months) and summer (7 months), which can further be sub-divided into four rainy seasons namely winter, post-winter, summer, and post-summer seasons.

Keywords

Climatology, Fluctuation, Seasonal Fluctuation, Hajjand Ummrah, Summer, Winter, Wettest, Hottest

1. Introduction

Climate Change particularly the global warming and its impacts on the environmental condition have attracted a great deal of interest to their theoretical and applied value. However, recently the change in temperature and rainfall in Saudi Arabia shows drastic changes as compared to the past.

The climate of Madinah-Al-Munawara province is marked by desert climate at the east and maritime climate at the west having hot days and moderate nights. The distribution of weather elements in Madinah-Al-Munawara generally is due to the altitudinal and latitudinal zones of horizontal atmospheric convergence and divergence, the maritime or continental origin of prevailing air masses and the seasonal shifting of the zonal pressure and wind system. The local convectional system, which results from diurnal surface heating, also causes variation in the annual distribution of the weather elements. A lot of researchers studied the weather and climate changes in Saudi Arabia but none of them discussed the climate of Madinah-Al-Munawara in detail. The most outstanding researchers, who worked on the climate of Madinah-Al-Munawarah are: FAO (2002) [1], IPCC (2001 and 2007) [2], GOSA (2010) [3], Zawad (2010) [4], Assiri and Darfaoui (2009) [5], Khan (1993) [6], Saab and Tolba (2009) [7], Mazroui and Abdullah (1998) [8], Rehman (2012) [9], Shanti *et al.* (2004) [10], Gebeily and Rehman (2010) [11], and Smith (2010) [12], and UNESCO (1984) [13].

The current study deals with Madinah-Al-Munawara that receives total annual precipitation of 36.2 mm (1.5 inches). The area is located on the country's west side, along the Red Sea coast. The precipitation is not sufficient for the plant growth and fall in arid climate. The study area covers an area of 151,990 km² and a population of 1,512,724 per 2004 Census. Madinah-Al-Munawara located at 39°-37' East longitude and 24°-25' North latitude on the globe (**Figure 1**).

2. Methods and Data

The study deals with the weather and climate fluctuation of Madinah-Al-Munawara taking into account the mean monthly and mean annual temperature, precipitation, and extreme events from 1959 to 2012 (52 years). The weather data obtained from the Meteorological Department, Madinah-Al-Munawara, Saudi Arabia. The monthly and annual averages and deviation from the mean have been calculated for each weather element and tabulated for the analysis. The monthly and annual data have been further processed into seasonal means and deviation that led to the fluctuation of hot/dry or moderate/wet period of the observatory.

For seasonal variation, the year has been divided into two main seasons that is summer and winter, so that months of the year having positive deviation from the mean considered as summer months and otherwise winter. Based on total annual precipitation, these two main seasons are further sub-divided into four sub-rainy seasons that is winter season (November to mid-February), post winter season (Mid-February to May), summer season (June to Mid-August), and post summer season (Mid-August to October). The precipitation as well as temperature shows a decrease/increase in the months of February and August, therefore these two months of the year have been divided by two and half of the month added to each season. For all variables the data has been subjected to various statistical techniques like deviation from the mean, averages, sum, time series etc. and the results are shown on tables, charts, and graphs.

3. Findings and Discussions

3.1. General Climatology

Temperature and precipitation are generally the most important climate elements. No description of the climate environment can be completed without a notation of the prevailing temperature and precipitation tendency especially of its distribution in time and place. Temperature and precipitation condition of a place provides a working condition for all physiological and ecological processes. This is at once revealed by fact that many and most of the bio-climate indices are based on temperature and precipitation.

3.1.1. Mean Monthly Temperature

The temperature of the study area is fairly representative of the plain strip of land at the eastern coast of Red Sea with continental plain and marine climates having hot long summers and warm short winters (**Figure 2**). The mean monthly temperature of the city is 28°C having maximum temperature of about 34°C and minimum of 21°C. The area has moderate temperature in winters when the mean monthly temperature drops to 21°C and hot

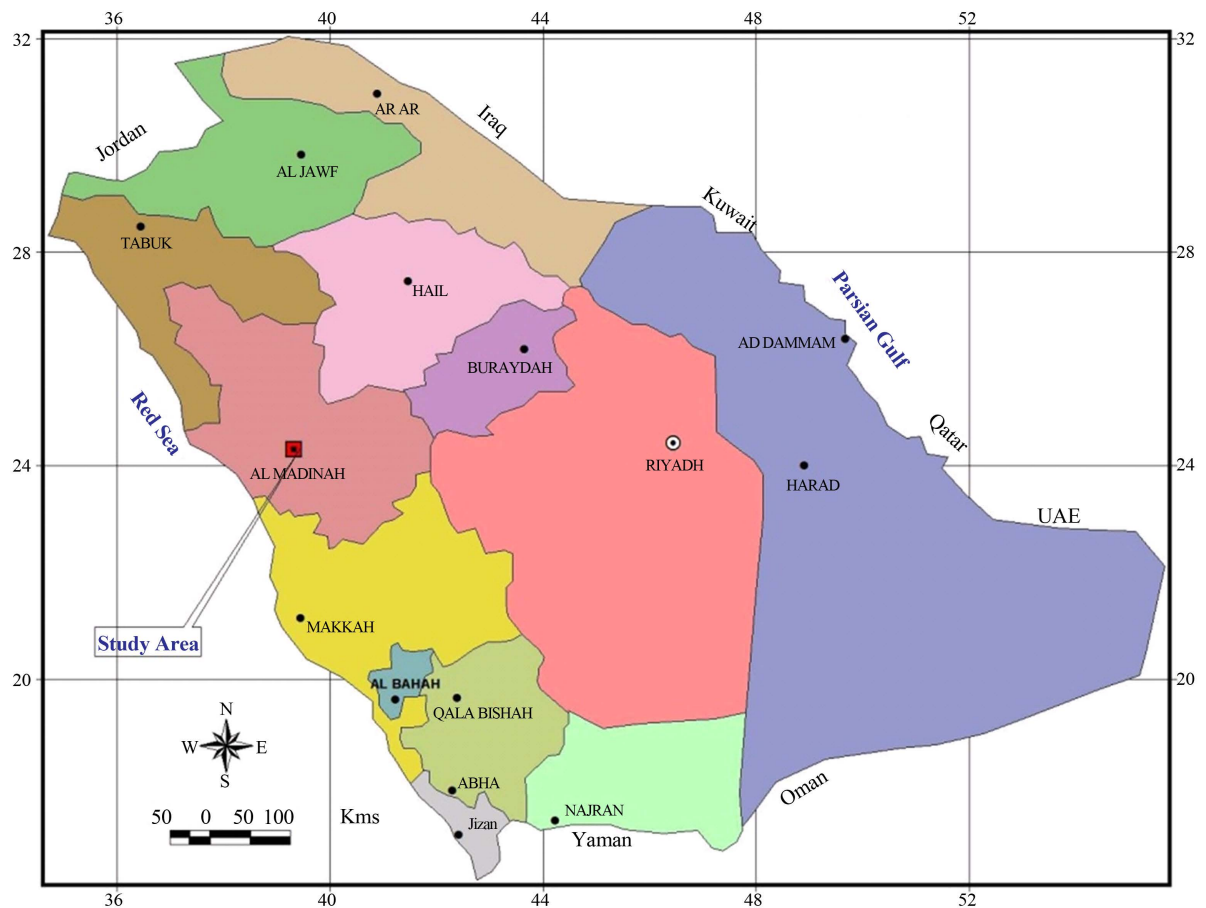


Figure 1. Madinah-Al-Munawara, Saudi Arabia, location map.

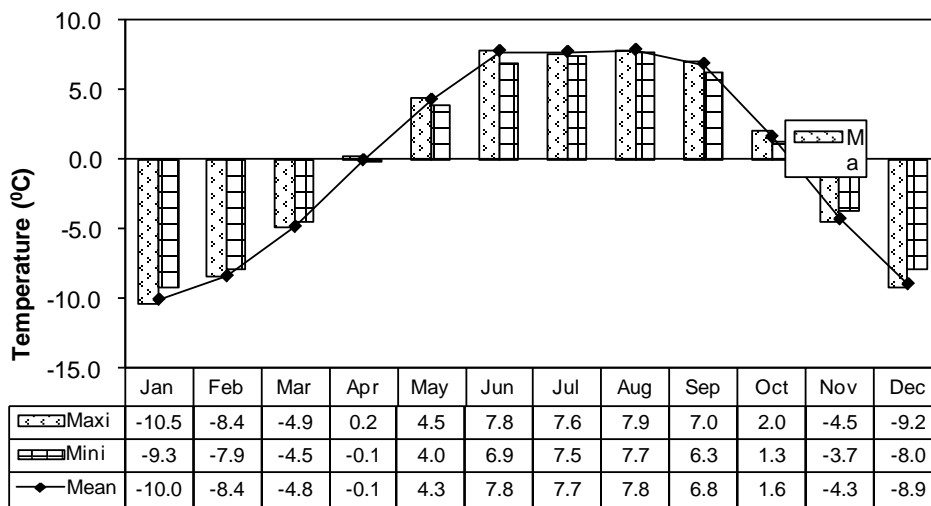


Figure 2. Madinah-Al-Munawara mean monthly, mean monthly maximum and minimum temperature (1959-2011).

summers when it rises up to and above 33 degree Celsius. The highest mean monthly temperature of the area is 36°C with a maximum of 42°C and minimum of 29°C in June and August, respectively and being hottest months of the city. The lowest mean monthly temperature of 18°C with 24°C maximum and 12°C minimum temperature recorded in January and constitutes as a coldest month of the area (Table 1).

Table 1. Madinah-Al-Munawara mean monthly temperature (°C) and precipitation (mm).

Moths	Mean Temperature	Maximum Temperature	Minimum Temperature	Precipitation
Annual Average	28.3	34.3	21.1	36.2
Winter Season	21.0	26.8	14.4	22.6
Summer Season	33.4	39.6	25.9	13.6
Winter Season	17.9	22.9	12.2	18.6
Post Winter Season	23.6	28.9	17.3	12.9
Monsoon Season	30.0	42.1	28.5	4.5
Post Monsoon Season	27.7	32.9	21.4	0.1

Source: Meteorological Department Madinah-Al-Munawara, Saudi Arabia (1959-2011).

The annual cycle of temperature reveals that the temperature condition of the area rises up from January to August and slackens till December (**Figure 2**). This variation in the annual temperature of the area is a result of annual revolution of the earth, angle of the sunrays, annual revolution of the earth, and the precipitation indices. The deviation of mean monthly maximum and minimum temperature reveals that it is below the mean condition from November to March and placed in winter months, whereas it is above the average line from April to October and considered as summer months of the area. This shows that there are two main seasons in the area that is summer which lasts from April to October (7 months) and winter that lasts from November to March (5 months). The extreme average maximum temperature of the city is 36.9°C recorded in 2010 with a minimum of 19.9°C recorded in 1999 having 31.1°C mean monthly temperature in 1966 during the period of 1959-2011 and being the hottest years of the area. The lowest mean monthly temperature of 26.7°C (1992) with mean monthly lowest maximum of 32.9°C (1959, 61, 82), and mean monthly minimum of 19.9°C recorded in 1992 and being coldest years of the series (**Table 2**).

3.1.2. Mean Monthly Precipitation

After temperature, precipitation is the most important of the climate elements. The agriculture or postural utilization of the land is the only real and lasting source of wealth, and both of these are in a large measure dependent on precipitation. The yield of crops varies with the precipitation in such a way as to leave no doubt that the precipitation has been the real determinant, and the carrying capacity of grazing land in head of stock per square kilometers emphasis the same truth. It also influences the rate of evapo-transpiration from vegetation and soil, which not only, affects the production of crops but also increases the ratio of moisture in atmosphere. The size and growth of vegetation is also closely related to the amount of precipitation. Sometimes, it also plays vital role in the industrial location and disease controlling of an area.

Annual rainfall is probably the most important simple climate indicator of productivity. The total precipitation of the city is 36.2 mm (1.5 inches), which is insufficient for plants growth and the city fall in arid climate. The heaviest precipitation of 11.8 mm recorded in November (moistest) and lowest of 0.0 mm in June and September (driest). The total precipitation of the area is 22.6 mm in winters that dropped to 13.6 mm in summers (**Table 1**). The heaviest precipitation of the area ever been recorded is 193 mm in 1995 and the lowest of 0.0 mm recorded for 17 years during 1959-2011 (**Table 2**). In general, higher precipitation occurred in the months of April, July and November.

The average precipitation indicates that it increases with decrease in temperature from November to March, while at the rise of temperature a decrease occurs from April to October (**Figure 2**, **Figure 3** and **Table 1**).

4. Seasonal Distribution

In order to study the seasonal variation of temperature and precipitation, the year has been divided into two main seasons *i.e.* summer and winter. The inter-relation of factors affecting climate of Madinah-Al-Munawara shows that the summer month in coastal areas may not be the summer month inland, and a summer month in plain may not be that of the mountains. Therefore, months of the year having positive deviation from the mean temperature are considered as summer months, otherwise winter (**Figure 2**). Generally, in Madinah-Al-Munawara, the summer lasts from April to October (7 months) and winters that lasts from November to March (5 months). The annual

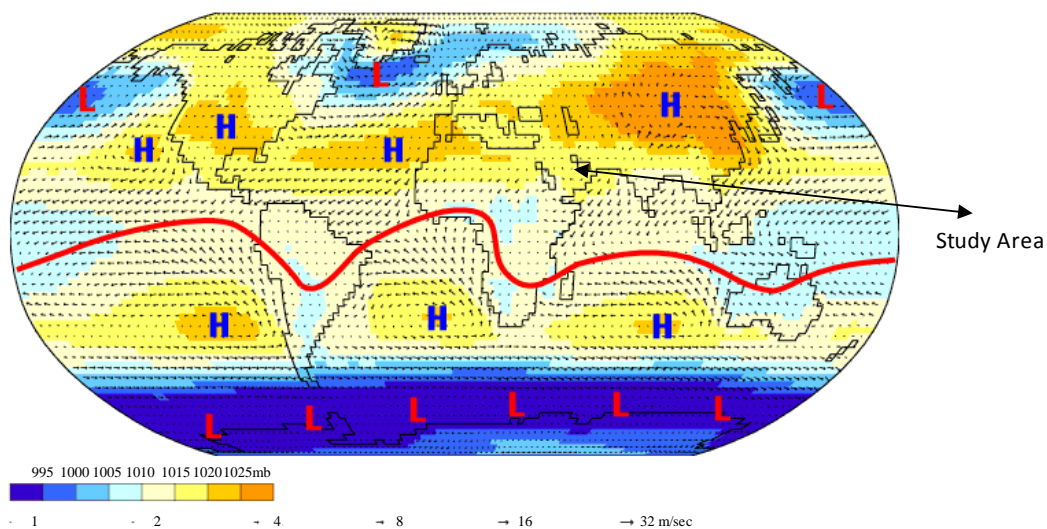


Figure 3. Sea level pressure and surface winds in January, by NCEP/NCAR reanalysis project, 1959-97/ climatologies.

Table 2. Madinah-Al-munawar mean monthly temperature (°C) and precipitation (mm)).

Years	Mean T	Max_T	Min_T	Rainfall	Years	Mean T	Max_T	Min_T	Rainfall
1959	27.2	32.9	20.6	33.3	1990	28.4	35.2	20.9	129.5
1960	28.6	34.3	22.1	80.3	1991	28.4	35.0	21.3	145.0
1961	27.4	32.9	20.9	39.1	1992	26.7	33.3	19.9	28.2
1966	31.1	36.6	24.7	0.0	1993	28.0	34.7	20.9	135.9
1967	27.7	33.3	21.2	0.0	1994	28.0	34.5	21.2	190.3
1968	28.0	33.5	21.7	0.0	1995	28.7	35.0	21.7	193.0
1973	28.8	34.7	22.0	0.0	1996	29.1	35.6	22.2	27.9
1974	28.4	33.8	21.3	0.0	1997	27.8	34.0	21.0	6.1
1975	28.4	33.9	21.2	0.0	1998	29.0	35.8	21.8	0.0
1976	28.8	34.1	20.8	0.0	1999	29.3	35.9	21.9	0.0
1977	28.9	33.9	20.2	0.0	2000	28.8	35.5	21.4	0.0
1978	28.8	34.5	20.8	1.0	2001	29.2	36.0	21.9	0.8
1979	28.9	34.6	21.0	52.1	2002	28.9	35.5	21.8	2.0
1980	28.8	34.8	21.0	7.1	2003	29.1	35.8	21.8	0.0
1981	28.9	34.7	21.4	0.0	2004	29.1	35.7	21.7	70.1
1982	27.1	32.9	20.0	4.1	2005	29.1	35.6	22.0	0.0
1983	27.5	33.7	20.3	3.1	2006	28.7	34.9	21.6	39.4
1984	27.9	34.1	20.5	5.1	2007	29.0	35.5	21.7	5.1
1985	28.0	34.3	20.9	0.0	2008	28.8	35.1	21.5	31.5
1986	27.8	34.1	20.6	0.0	2009	29.2	35.7	21.8	18.3
1987	28.6	35.2	21.3	0.3	2010	30.2	36.9	22.7	114.8
1988	28.7	35.2	21.3	0.0	2011	28.8	35.3	21.7	69.9
1989	28.1	34.5	21.0	6.6	Average	28.4	34.2	21.2	32.0

Source: Meteorological Department Madinah-Al-Munawara, Saudi Arabia (1959-2011).

cycle of precipitation shows two positive and two negative deviations from the mean condition (Figure 4). So these two main seasons of the city are further divided into four sub-rainy seasons. The winter season that lasts from November to mid-February (Moist), post winter season from Mid-February to May (Moderate), Monsoon season from June to Mid-August (Hottest), and post Monsoon season from Mid-August to October (Warmer). The characteristics of each season are as follow.

4.1. Winter Season

The winter rainy season of Madinah-Al-Munawara lasts from November to Mid-February. During this season, the climate of Madinah-Al-Munawara is controlled by the interaction of Siberian high pressure, the Mediterranean lows (western Depressions) and the Sudan trough. The Mediterranean cyclones, which travel from west to east in association with upper troughs and active phases of subtropical and polar jets, are the main sources which cause precipitation during these months in the area. Their potential generally decreases from north to south except for the mountainous areas, where uplift motion acts as a trigger factor for the uplifting of winds into the condensation level. During winter season, the ridge of the Siberian high extends into the northeastern regions of Saudi Arabia. The trough of the Sudan low brings warm humid air in the lower atmospheric layer to the south-western parts of the country. When the cold air which is associated with the Siberian ridge extends especially far into the southern region and the humid air from the Sudan trough is concentrated along the Red Sea, the rainfall that occurs in this case is due to both instability and orography (Figure 3).

The rainfall generated by these western disturbances of the cooler season is usually fairly widespread and light to moderate. Since this fall in the cool season, when losses from evaporation are low, is highly effective for the growth of winter crops. The season is usually characterized by moderate weather with low mean monthly temperature and moderate rains. These disturbances provide a total of 18.6 mm precipitation in the city and count as the moist season of the area. The heaviest fall is observed in the month of November (11.8 mm), while the lowest is 0.3 mm in January. The general pattern of the precipitation during these months shows a decreasing trend from November to February (Figure 4). In winter, the mean monthly temperature of the city is dropped to 17.9°C, mean maximum temperature of 22.9°C, while the mean minimum temperature is 12.2°C with clear skies.

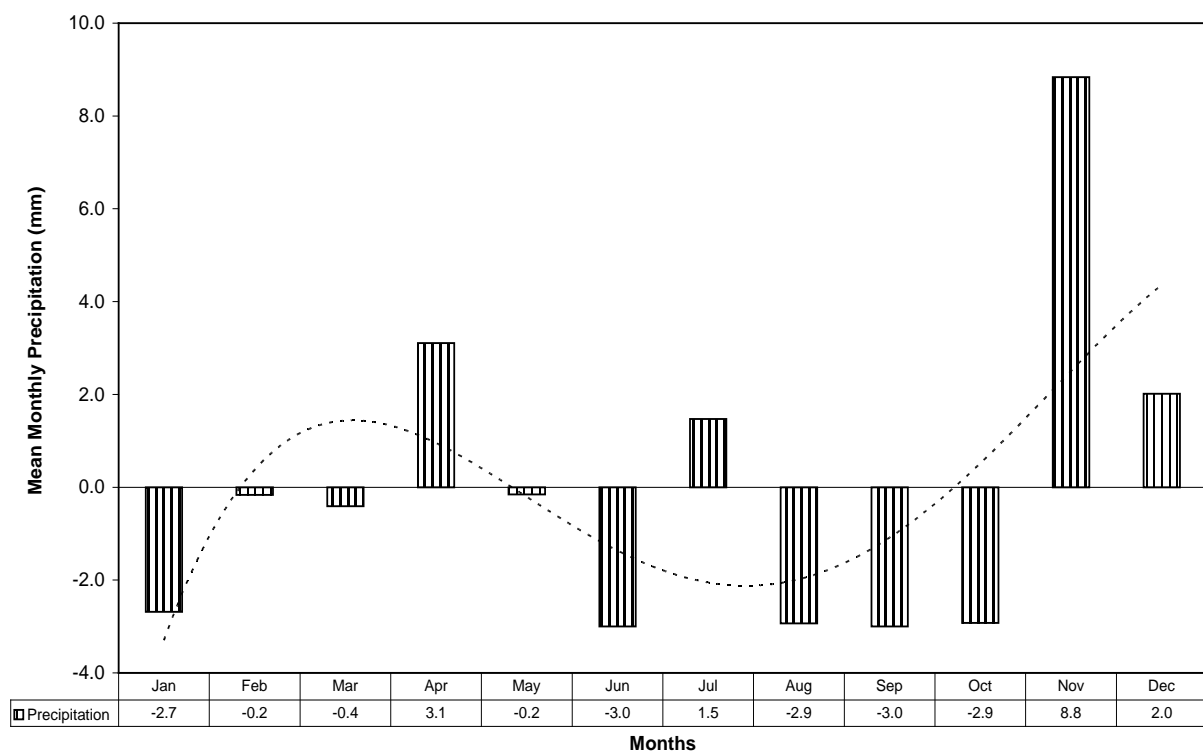


Figure 4. Madinah-Al-Munawara deviation of mean monthly precipitation from the mean (1959-2011).

4.2. Post Winter Season

This season ranges from mid-February to May and is characterized by moderate temperature and low precipitation. It is some time called as the cool moderate season of post winter and the pre-hot wet season of summer and early fall. From Mid-February to April, the anticyclones subsidence and clear skies, characteristic of the winter months still prevails and this in combination with a much stronger solar radiation sets the weather pattern for the season. Temperatures are high and a heavy, dry haze envelops in the interior, but drought still grips most of the city.

The post winter season, in general, is characterized by violent weather, in the form of thunderstorms and squalls. The rainfall accompanying this vigorous convective system is low, but occasionally well-developed cumulonimbus clouds, are generated with strong squall wind, and violent dust storms.

In post winter season, the mean monthly temperature exceeds 23.6°C, mean maximum temperature of 28.9°C and mean minimum temperature of 17.3°C with rare rains (Table 1). These are the specific determinants, which caused parching of leaves in plants and evaporation of sweats from human bodies. In post winter season, the area of Madinah-Al-Munawara is still under the influence of western depression associated with convection caused by the local heating that causes thunderstorms and caused rains (Figure 4).

4.3. Summer Season

The summer season of Madinah-Al-Munawara varies from June to Mid-August (Figure 2).

The deflected monsoon currents, generally, travel northwards towards Saudi Arabia on the shores of the Arabian Sea. This branch of monsoon reaches to Saudi Arabia at Mid-June and reaches to its climax in July. However, it is of low vertical extant and generally, produces stratus clouds in the coastal areas and cumulus clouds in plains and causes heavy rains in the month of July with low pressure and high temperature on the continental area. The monsoon currents remain steady till it begins retreating towards the beginning of August. The variation in precipitation intensity from monsoon is due to its long trajectory decreasing the moisture index of these depressions as they travel over continental areas. These winds are the only source of summer rains in Madinah-Al-Munawara, which keep temperature low in the month of July. These winds give torrential rains with showers and cause damage in different sectors of the human life (Figure 5).

The later arrival of monsoon currents in Saudi Arabia may results from the fact that during the winter and post winter, there is an orographically determined upper trough, oriented north south at about 85°E, over the western Bay of Bangal. It acts to accelerate the southwesterly monsoon flow over Burma located east of this trough, while at the same time retarding it over Indo-Pakistan and Arabian Sea to the west (Yin, 1949) [14]. As the sub-continent is heated intensively in April and May, the zonal westerly start to move northward and it changes

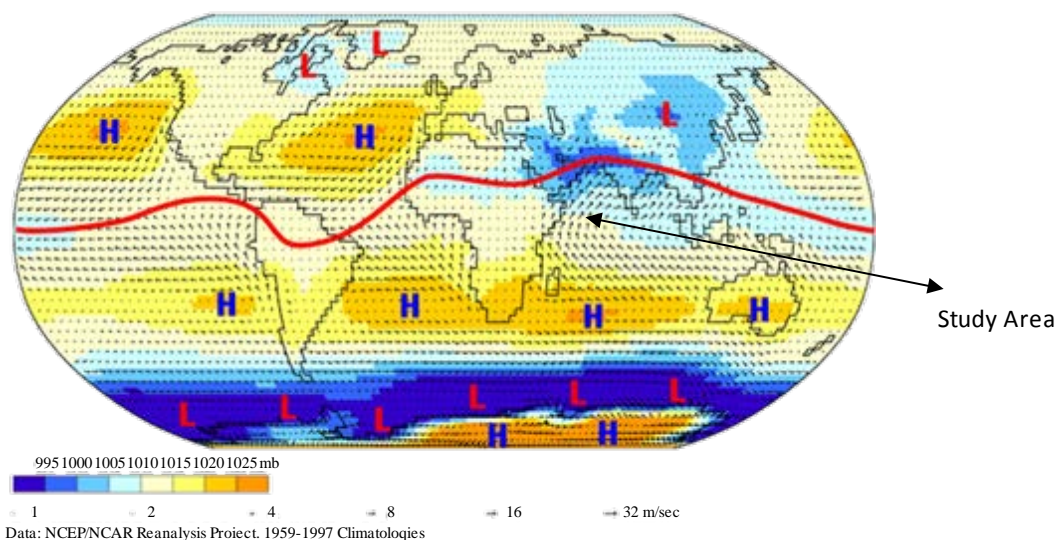


Figure 5. Sea level pressure and surface winds in July, by NCEP/NCAR reanalysis project, 1959-97/ climatologies.

its direction towards southwest. As a result, the jet stream, which had been at about 30°N during winter and post winter, tends to disappear. Disappearance becomes more frequent as the season advances and each disappearance is associated with a northward surge of the summer monsoon. Finally, in late May or early June, the jet disappears completely over Saudi Arabia and takes up a position at about 40°N. Simultaneously, there occurs a shift of the low latitude trough and ridge positions, and the upper trough which previously was located at about 85°E quickly moves westward some 10° and takes up a position over western Indo-Pakistan sub-continent at approximately 75°East. The heating of the Middle East and the development of a surface pressure trough are unable to produce a northward advance of the ITC until large scale dynamic features of the circulation aloft become favorable (Trewartha, 1961) [15]. When the jet stream reappears at Saudi Arabia, again in fall, the summer monsoon again retreat southward and is called reversible monsoon.

During this season, the total precipitation of Madinah-Al-Munawara is 4.5 mm having heaviest of same value in July and lowest of 0.0 mm in June and being the moist and driest months of the season. The mean monthly temperature of the city is raise to 30°C with mean monthly maximum temperature of 42.1°C and mean monthly minimum temperature of 28.5°C with hot gusts and sandy storms. The area is extremely hot during these months due to sun burning over head rays and low moisture (Table 1).

4.4. Post Summer Season

The season varies from Mid-August to October and is characterized by pleasant weather with moderate temperature and low rainfall. During this season the low pressure of land areas shifts towards the Arabian Sea and converse happens on the continent. This change in the pressure system causes change in the direction of the monsoon from southeast towards southwest. Consequently, the monsoon winds start blow from land towards ocean and designated by the name reversible monsoon. By the late fall, the trough of low pressure, separating the easterly and westerly air currents establishes over the southern part of Saudi Arabia. Along the discontinuity between the equatorial westerly and the zonal easterly, various kinds of perturbations develop ranging all the way from weak monsoon depressions to hurricanes. The depressions follow less well definite tracks than in summer, but in general, their progress is westward, so that their rainfall effects are concentrated in coastal region of Saudi Arabia.

During the fall months, the dynamic features of the circulation aloft, including jet stream and the orographically imposed troughs and ridges, begin to approach their cool season positions, with the reappearance at Saudi Arabia in September and October of the middle latitude westerly and the jet stream, and the reestablishment of the Polar front over the Mediterranean Sea/Europe. The western disturbances once more become an important control of weather in Saudi Arabia (Trewartha, 1961).

In post summer season, the mean monthly temperature of the Madinah-Al-Munawara falls to below 30°C with mean monthly maximum temperature of 33°C, and mean monthly minimum temperature of 21.4°C. The total means monthly precipitation of Madinah-Al-Munawarah remains low that is 0.1 mm. In these months the monsoon lows give way to those of winter currents (western depression) and most of the rains are caused by local thunderstorms or reversible monsoon winds, which develop due to local high pressure and heating on the inland areas. The retreat of monsoon from north Arabian Sea is marked by disappearance of the stratus clouds with a gradual increase in daytime temperature (Table 1, Figure 4).

5. Climate Fluctuation

The variability of a climate is best explained as typical pattern of variation within such standard period. Most of these variations are quite short-term (e.g. between successive years) and periodic. Some of it, however, is truly periodic. Such variation includes daily and seasonal changes, forced by the regular behavior of the sun. Some of the variations may appear quasi-periodic, but this is usually without value for prediction, especially as regards precipitation.

5.1. Temperature Fluctuation

The natural, physical, and socio-economical ecosystems of Madinah-Al-Munawara are not only dependent on how much temperature rises or falls but also on how it varies from year to year and time to time. Generally, the mean monthly, mean maximum and minimum temperature of the area show an increasing trend during 1959-

2011. The temperature of the city remains low during the period where the concentration of precipitation remains high and converse condition during dry years. During 1959-1995, the trend of temperature was below the mean condition and turned to positive deviation onward till 2011. From 1961-1989, there was a rise in the temperature of the city whereas it remained low from 1990 to 1997 and rose up till 2003 and inversed till 2011 (Figure 6).

The deviation from the annual mean of temperature shows clear picture of the temperature condition in the city. The temperature of the city shows a gradual increase from 1959-1980 and negative trend from 1981-95 and remained high during 1996-2011. Consequently, there were ups and downs in the temperature condition of Madinah-Al-Munawara after each fifteen years, having periodic pattern (Figure 7). The mean monthly temperature of the city show an increase of 1.7°C having 1.2°C in mean monthly maximum and -1.9°C in mean monthly minimum temperature during 1959-2012 (Table 3). The highest positive deviation of 2.6°C in mean monthly temperature is recorded in 1996, 2.2°C in mean monthly maximum temperature and 1.3°C mean monthly minimum temperature in 2010 respectively. Generally, the deviation from the mean temperature condition of the city shows an increase in mean monthly and mean monthly maximum temperature, while it indicates a decreasing trend in the mean monthly minimum temperature.

5.2. Precipitation Fluctuation

After temperature, precipitation is the most important weather element that maintains stability in the water resources and agriculture activities in the area. Besides, it also plays a vital role as a controlling factor of temperature. The annual trend of precipitation shows that the area remains dry during 1961-78, wet during the period of 1979-85 and reversed during 1986-89. During 1990-2011 the precipitation of the area shows an increasing trend with a dry period of four years during 1998-2001 (Figure 6). The area falls in arid climate and drought condition prevails in the city for most of the years. The longer and most severe drought of the city was observed during 1962-77 (15 years), and moderate drought in 1978-88 (10 years).

Generally, the sum of deviation from the mean condition of precipitation shows a total decrease of -0.3 mm having an annual average of precipitation 0.0 mm during 1959-2011. Overall, the trend of precipitation at Madinah-Al-Munawara shows an increasing trend throughout the series (Figure 8). The high positive deviation of 161 mm of the city was recorded in 1995, while the lowest of -32 mm observed in more than 10 years (Table 3).

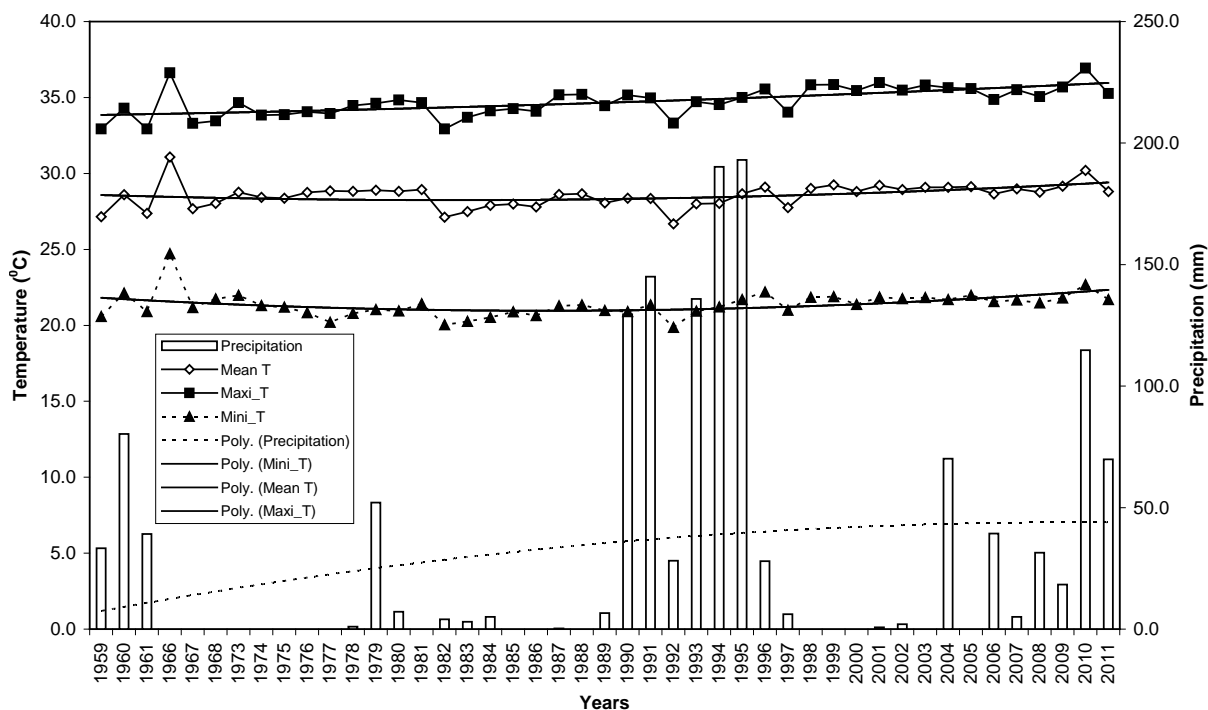


Figure 6. Madinah-Al-Munawara annual trend of mean monthly temperature (°C) and precipitation (mm).

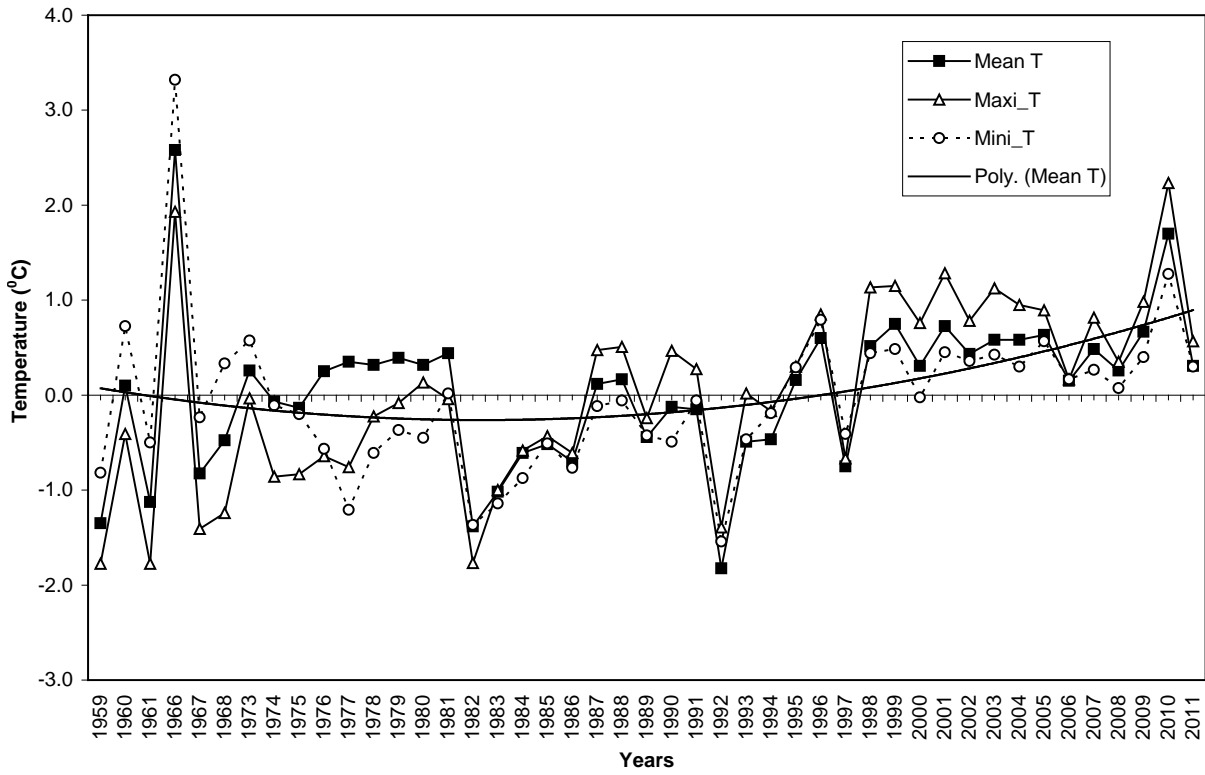


Figure 7. Madinah-Al-Munawara deviation of mean monthly, maximum and minimum temperature (°C).

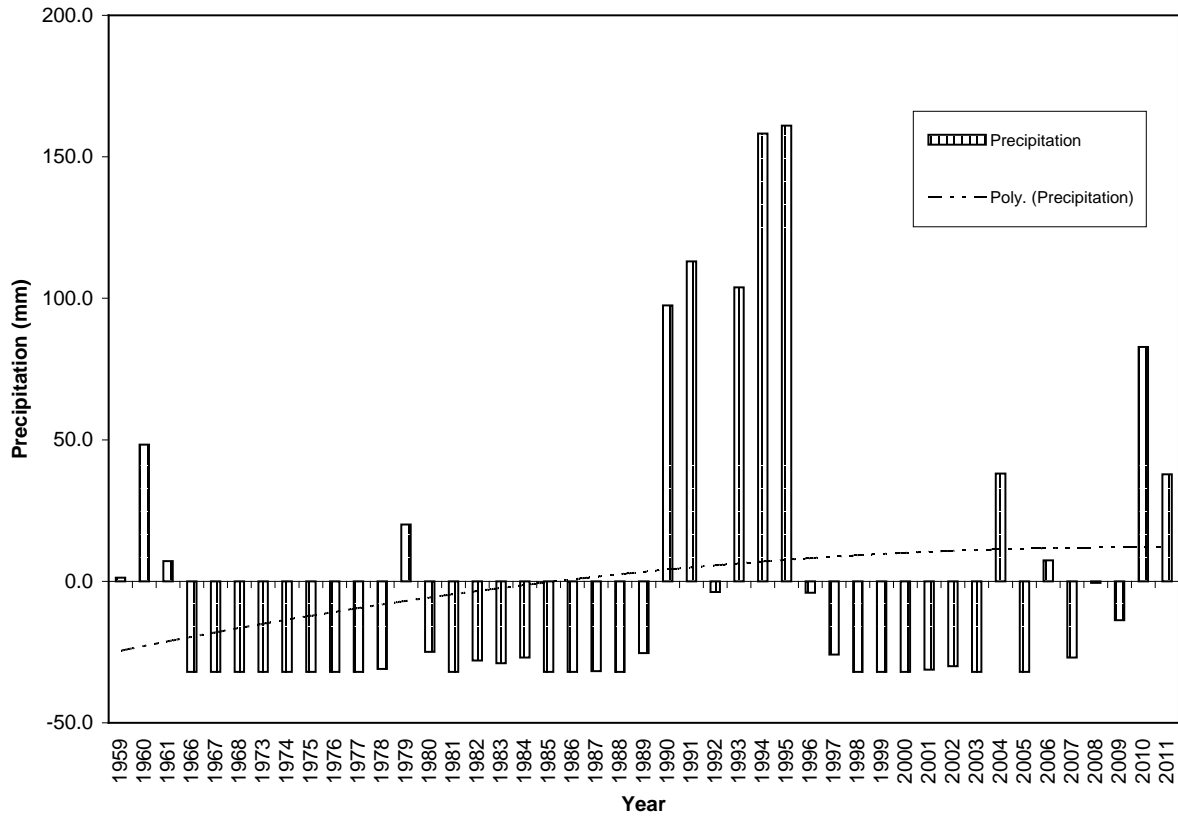


Figure 8. Madinah-Al-Munawara deviation of mean monthly precipitation (mm).

Table 3. Madinah-Al-Munawara deviation of temperature (°C), and precipitation (mm) from the mean (1959-2011).

Years	Mean Temp	Maxi Temp	Mini Temp	Rainfall	Years	Mean Temp	Maxi Temp	Mini Temp	Rainfall
1959	-1.4	-1.8	-0.8	1.3	1990	-0.1	0.5	-0.5	97.5
1960	0.1	-0.4	0.7	48.3	1991	-0.1	0.3	-0.1	113.0
1961	-1.1	-1.8	-0.5	7.1	1992	-1.8	-1.4	-1.5	-3.8
1966	2.6	1.9	3.3	-32.0	1993	-0.5	0.0	-0.5	103.9
1967	-0.8	-1.4	-0.2	-32.0	1994	-0.5	-0.2	-0.2	158.3
1968	-0.5	-1.2	0.3	-32.0	1995	0.2	0.3	0.3	161.0
1973	0.3	0.0	0.6	-32.0	1996	0.6	0.8	0.8	-4.1
1974	-0.1	-0.9	-0.1	-32.0	1997	-0.8	-0.7	-0.4	-25.9
1975	-0.1	-0.8	-0.2	-32.0	1998	0.5	1.1	0.4	-32.0
1976	0.3	-0.6	-0.6	-32.0	1999	0.8	1.2	0.5	-32.0
1977	0.4	-0.8	-1.2	-32.0	2000	0.3	0.8	0.0	-32.0
1978	0.3	-0.2	-0.6	-31.0	2001	0.7	1.3	0.5	-31.2
1979	0.4	-0.1	-0.4	20.1	2002	0.4	0.8	0.4	-30.0
1980	0.3	0.1	-0.4	-24.9	2003	0.6	1.1	0.4	-32.0
1981	0.4	0.0	0.0	-32.0	2004	0.6	0.9	0.3	38.1
1982	-1.4	-1.8	-1.4	-27.9	2005	0.6	0.9	0.6	-32.0
1983	-1.0	-1.0	-1.1	-28.9	2006	0.1	0.2	0.2	7.4
1984	-0.6	-0.6	-0.9	-26.9	2007	0.5	0.8	0.3	-26.9
1985	-0.5	-0.4	-0.5	-32.0	2008	0.3	0.3	0.1	-0.5
1986	-0.7	-0.6	-0.8	-32.0	2009	0.7	1.0	0.4	-13.7
1987	0.1	0.5	-0.1	-31.8	2010	1.7	2.2	1.3	82.8
1988	0.2	0.5	-0.1	-32.0	2011	0.3	0.6	0.3	37.9
1989	-0.4	-0.2	-0.4	-25.4	Sum	1.7	1.2	-1.9	-0.3

Source: Meteorological Department Madinah-Al-Munawara, Saudi Arabia (1959-2011).

During 1960-90, the deviation from the mean shows a negative trend and the area remained under a long drought condition. From 1991-96 the trend shows a positive deviation having heavy rains in some years and count as wet period of the Madinah-Al-Munawara. The trend in precipitation takes a negative deviation during 1997-2009 and converse onward till 2011.

6. Conclusions

- Madinah-Al-Munawara receives less than 2 inches (50.8 mm) precipitation annually and considered arid continental climate. However, the coastal region of the province is characterized by land and ocean breezes and shows a maritime climate.
- The annual march of temperature reveals that the temperature condition of the area rises up from January to August and slackens till December. The mean monthly temperature of the city recorded during 1959-2011 is 28.3°C having maximum temperature of about 34.3°C and minimum of 21.1°C. The area has moderate temperature in winters when the mean monthly temperature is dropped to 21°C and hot in summers when it rises up to above 33 degree Celsius.
- The extreme average maximum temperature of the city is 36.9°C recorded in 2010 with a minimum of 19.9°C recorded in 1999 having 31.1°C mean monthly temperature in 1966 during the period of 1959-2011 and being the hottest years. The lowest mean monthly temperature of 26.7°C (1992) with mean monthly lowest maximum of 32.9°C (1959, 61, 82), and mean monthly minimum of 19.9°C recorded in 1992 and

being a coldest years of the series.

- Madinah-Al-Munawara characterized by two main seasons that is summer season that lasts for seven months (April to October) and winter season for five months (November to March). The summers of the city are extremely hot, while the winters are warm. The highest mean monthly temperature of the area is 36.1°C with a maximum of 42.2°C and minimum of 28.8°C in June and August with dust storms and being hottest months of the city. The lowest mean monthly temperature of 18.3°C with 23.8°C maximum and 11.8°C minimum temperature recorded in January, constitutes as a coldest month of the area.
- The total precipitation of the city is 36.2 mm (1.4 inches), which is insufficient for plants growth having arid continental climate with hot long dry summers and short warm winters. The heaviest precipitation of 11.8 mm recorded in November (moistest) and lowest of 0.0 mm in June and September (driest). The heaviest fall of the area ever been recorded is 193 mm in 1995 and the lowest of 0.0 mm recorded for 17 years during 1959-2011. In general, higher rain fall occurred in the months of April, July and November.
- The average precipitation indicates that it increases with decrease in temperature from November to March, while at the rise of temperature a decrease occurs from April to October. In April, it exceeds 6.6 mm and then decreases till October and increase again onward up to November 8.8 mm.
- The two main seasons of Madinah-Al-Munawara that is winter and summer is further sub-divided into four rainy seasons. These are winter season (November to mid-February), post-winter season (Mid-February to May), Monsoon season (June to Mid-August), and post Monsoon season from (Mid-August to October).
- The mean monthly temperature of the city shows an increase of 1.7°C having 1.2°C in mean monthly maximum and -1.9°C in mean monthly minimum temperature during 1959-2011. In general there are ups and downs in the temperature condition of the area after each 10 and 15 years.
- The area falls in arid climate (36.2 mm total Precipitation) and drought prevails in the city for most of the years. The longer and most severe drought of the city observed during 1962-77 (15 years) and moderate drought in 1978-88 (10 years). Generally, the sum of deviation from the mean condition of precipitation shows a total decrease of -0.3 mm having an annual average of precipitation 0.0 mm during 1959-2011. Overall, the trend of precipitation at Madinah-Al-Munawara shows an increasing trend throughout the series and it is expected that the precipitation condition of the city will increase with passage of time.
- The heaviest precipitation of Madinah-Al-Munawara recorded in the month of April and November and constituted wettest months of the year. The lowest precipitation of the city seems in June, August, September and October that marked it as driest months of the year having high temperature and evapo-transpiration.

7. Recommendations

- The explosive materials used in wars and burning of oil wells particularly in Gulf war are more dangerous to the Green House of the physical environment. Therefore, it is needed to control wars in the region and to solve the problems with negotiation instead of using power and to provide peace to the environment of the planet earth.
- Industrialization and vehicles are the major contributors that exhaust green house gases into atmosphere. Therefore, it is necessary to improve automobile engines, industrial machineries with new trend and techniques, and to design policy for the controlling of chlorofluorocarbons, and awareness of people about the ongoing environmental issues.
- The scarce and sparse forests of Middle East is major factor that exposed soil surfaces to radiation and causes change in the evapo-transpiration and also increase atmospheric turbidity. Therefore, legislation is needed to prevent sever cutting of forests and also to ensure the immediate replanting of trees particularly on the mountains slopes and barren lands round the city of Madinah-Al-Munawara, and to make a policy for its protection and preservation. The more suitable plant for the plantation in desert area is Acacia, which has low water requirement and also help to pick the water table into surface of the earth.
- The famous conference about, “how to combat global warming” are: Vienna convention for the protection of the ozone layer (1985), Montreal protocol (1987), UN Earth Summit (1992), Kyoto protocol (1997), Agenda-21 (2002), and IPCC (2007) etc, but the conditions presented in these conferences were not fully implemented on international level. It is therefore, recommended that the countries of Middle East must plan a criteria to collect funds and to fight for the green revolution in the entire region together.
- For intensive afforestation, it is more appreciable to provide facilities to the inhabitants of the area and to

encourage the community reforestation. Also to initiate programs for the awareness of the locals about the roles of forests in green revolution and climate change.

- The ozone layer can be protected by replacement of chlorofluorocarbons by hydro-fluorocarbons released to atmosphere from aerosol, refrigeration and air conditioning, and foam Industries. Besides, afforestation, which releases oxygen in abundance to the atmosphere in turn plays a significant role in increasing concentration of ozone in the stratosphere, is highly appreciable in this regard.
- Further research is required to study the causes and impacts of climate change and global warming at Saudi Arabia so that by proper planning, the problem arising due to the temperature increase and reduction of precipitation is met with.

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