Journal of the Islamic University of Gaza v. 9 no. 2, p41 – p66 . 2001

VARIATION OF RAINFALL AND DROUGHT CONDITIONS IN GAZA-PALESTINE: ON a REGIONAL AND GLOBAL CONTEXT

Ahmed Khalil Ahmed El-Kadi [*]
Islamic University of Gaza,
P O Box, 108 Gaza Strip, Palestinian.
E-mail. kadi@Mail.iugaza.edu

تباين الأمطار وأحوال الجفاف في غزة- فلسطين على أساس إقليمي و عالمي

ملخص لقد تم تحليل الأمطار الشهرية، و الفصلية، و السنوية لمحطة أرصاد غزه للفترة من 1967-1998 باستخدام التحليل الإحصائي البسيط للتطرفات المعايرة المتراكمة للكشف عن التتابعات الزمنية للجفاف، ولقد عانت مناطق كثيرة في العالم منذ النصف الأخير للقرن المنصرم من حدوث أحوال جفاف متكررة . ولقد واجهت منطقه البحر المتوسط، و على وجه الخصوص الحوض الشرقي منه أحوال جفاف متكررة، و شديدة خلال العقود الأخيرة منذ السبعينيات إلي الآن.

هذا البحث يقدم أول محاولة لتحليل أمطار غزه و الهدف من هذا البحث هو معرفة ما إذا كانت أمطار غزه تظهر تباينات مشابهة، و علي وجه التحديد ظروف الجفاف التي حدثت في بلدان الحوض الشرقي للبحر المتوسط.

هذا البحث اظهر أن أحوال الجفاف في غزه مشابهة لتلك التي حدثت في مناطق الحوض الشرقي للبحر المتوسط، حيث إن ظروف الجفاف قد حدثت منذ العام 1967 لأواخر التسعينيات مع حدوث عدد قليل من السنوات الرطبة المتداخلة، و هذه تنسب بشكل رئيسي لحدوث عدد قليل من الأيام غزيرة المطر، و ليس إلي زيادة عدد الأيام الممطرة . الآليات أو العوامل الجوية وراء هذا الجفاف تم مناقشتها و ربطت مع ظروف الجفاف في غزه.

Abstract **The monthly, seasonal and annual total rainfall in Gaza for the period 1967-1998 is studied. The simple statistical method of the cumulative standardized anomalies (Z-scores) is**

---

[*] Assistant prof in M.phil, Ph,D, Climatology.

used to define and to delimitate the dry sequences of Gaza rainfall.
In the second half of the 20th century, there has been a worldwide repeated drought over many countries. In the Mediterranean, particularly the Eastern Mediterranean, drought conditions have been persistent in the last few decades with severe drought from 1970s onward. This is the first attempt so far to analyse the Gaza rainfall. The aim of this investigation is find out if the rainfall in Gaza shows similar rainfall fluctuations, in particular the drought conditions that prevail in the Eastern Mediterranean basin. The analyses of Gaza rainfall shows similar rainfall characteristics and drought conditions to those found in the Mediterranean. Drought conditions from 1967 to late 1990s with short-term wet years. Atmospheric mechanisms behind this drought has been reviewed and matched with variations of rainfall in Gaza.

Key words
Mediterranean, Gaza, Rainfall, Drought, Atmospheric Circulation, Climatic Change.

Introduction

Annual totals in Palestine are characterized by southward decreases and eastward increases, culminating in the hilly area in central and northern parts. Eastward from there, decreases towards aridity conditions. The isohyets in general run parallel to the coast and curve sharply westward in the Gaza strip.

The Atlantic Ocean and the Mediterranean Sea are the primary source region of the moist air masses caus which abundant rainfall. Trough and frontal-type midlatitude cyclones associated with upper level westerly flow are considered as the principal climatic control of rainfall (Turkes, 1996).

The Mediterranean climate is characterized by cold-season rainfall originating in the southward spread of the Jet stream during winter, accompanied by a southward shift of surface cyclone tracks (Zangvil and Drulan, 1990), which developed mostly during the cold season (Sahsamanoglou et al. 1991; Sarroni et al. 1996).

From Cypress there are three major depression tracks, one, northeast toward Turkey, does not affect the area at all. A second, eastward toward Syria causes rain in the northern part of the area. The third southeastward covering the whole country, causes rain in all parts (Kutiel, 1982).

It is well known that rainfall, which is an essential part of the hydrological cycle (Legates and Willmott, 1990), is characterized by high spatial and temporal variability, particularly in the Mediterranean region. In the recent decades there has been a growing concern in climatic change that has taken place in the world and in the Mediterranean particularly the Eastern basin. Great interest has recently focused on the dramatic fluctuation, particularly fluctuations in precipitation during the past century (Maheras and Kolyva-Machera 1990). The increasing evidence confirmed a consistent decrease in rainfall over the Mediterranean region. In the Eastern Mediterranean there are abrupt decreases over the last 30 years with a widespread drought event in the 1970s over Turkey and from 1982 onward dry condition prevail over the Mediterranean region of Turkey (Turkes, 1996). The annual total precipitation in the Balkans (1894-1985) showed that the1980-1985 were very dry years (Maheras and Kolyva-Machera 1990). A humid period was 1927-1944, and a dry period from 1945-1955 occurred over the Mediterranean and the whole of central and eastern Europe, and another dry period from 1968-1985 (Maheras, 1988). A significant long-term decrease in precipitation detected in the period (1880-1993) for the Mediterranean region in Spain was during the 1980s (Esteban-Parra et al. 1998), related to the intensification of the Azores high, and a long-term rainfall change indicated a significant decreasing trends over Greece and Turkey (Amanatidus et al. 1993).

Wheeler and Martin-Vide (1992) discussed Gibraltar rainfall for the period 1791-1990. They found a progressive decrease in the annual rainfall total from late 1960s onwards. Corte-Real et al. (1995) studied the relationship between Mediterranean surface climate and large-scale circulation over the Atlantic Ocean and Europe using canonical correlation analysis for the period 1951-1980. Sharon and Ronberg (1987) examined the regularity of intra-seasonal rainfall fluctuations in Israel relating a 10-day average to changes in synoptic condition. Moreover, Jacobeit (1987) extended this approach of analyses to examine whether this intra-seasonal fluctuation originated in behavior of the general circulation using daily height of 500hpa level for the decade 1966-1976. In his analysis of climatic fluctuation over Israel Striem (1991) showed that if the number of days with meridional flow increases the rainfall increases, and if the strength of westerlies increases the frequency of meridional rain spell types might decrease and thus cause drier, drought year and higher than normal temperature.

Ben-Gai et al.(1993) studied long-term changes in October rainfall in southern Israel including Gaza Strip, between the Mediterranean coastal plain and Negev desert using 51 rainfall stations and another 6 control stations to the north for the period 1938-1985. They used the least-square line as a function of time and spatial correlation maps. Ben-Gai et al. (1994) extended the same analyses in southern Israel in the period 1961-1994 using the coefficient of variation (C.V) and the differences between rainfall over the south and a number of control stations to the north of the area. They showed that the rainfall in south Israel had increased, and the proportion of rainfall in spring was 15-25% greater in 1951-1980 than in 1931-1960, while in winter it decreased by 10%. As their study depends on overlapping periods the result may not be straightforward.

Kutiel and Sharon (1981) used the same analysis to study the diurnal variation of precipitation in the northern Negev for two rainy seasons 1975-1977 and to characterize the rainfall as being widespread or spotty. They found that widespread rainfall is predominant during relatively cool morning hours and afternoon maximum of high-intensity rainfall, and the rainfall is most strongly localized in the afternoon being forced by surface heating driven small-scale convection, and least during morning hours due to instability condition near the ground. Similar analysis was used by Kutiel (1982) to identify areas with coherent rainfall patterns in term of parallel fluctuation for the period 1957-1977, and by Sharon (1978) to study daily rainfall in Israel and the western parts of Jordan for the period 1960-1967 for seeded and unseeded days.

It is well known that about 50% of the annual rainfall is reached considerably earlier at the coastal plain as compared to the mountain area. This is related to relatively high temperature differences of the land and sea during the beginning of the rainy season. The large supply of heat and moisture enhances the instability caused by the passage of cold fronts during this period. The effect diminishes with the progress of cooling sea surface temperature (SST) during winter and the effect of the mountains becomes pronounced (Goldreich and Manes, 1979).

Kutiel (1985) used daily total rainfall for the period 1958-1978 to study the fluctuation of the annual course of dry spells over Israel and found changes in the beginning and end of the rainfall season. Kutiel (1990) studied factors affecting the rainfall during the rainy season in different parts of Israel, using daily rainfall from the northern and central parts of Israel, for the periods 1958-1984 for the rainy season October-April. He used the C.V and regression analysis, and found that smaller percentage of rain days yield larger percentage of rain amount.

Kutiel (1991) studied recent changes in the patterns of the mean monthly sea level pressure over Europe, the Mediterranean and the Middle

East between the two normal periods of 1931-1960 and 1951-1980 for grid points 20-60^{o}N, 20-40^{o}E. He related variations of rainfall with variations in pressure patterns. Goldreich (1987) differentiated between the contribution of cloud seeding effects and urban-induced changes that possibly influence the rainfall spatial distribution over Israel's coastal plain for the periods 1950-1980, using regression analysis separately for seeded versus unseeded days. However, cloud seeding is presumed to enhance only rainfall yield during existing rain-days, but not to produce new rain days when rainfall conditions are lacking (Kutiel, 1990) The seeding processes lead to greater spatial variance in rainfall and very localized shower, and one might deduce that the seeding actually cause a negative effect (Goldriech, 1987).

Goldreich and Manes (1979) studied the rainfall in Tel-Aviv area and surrounding regions to detect the effect of urbanization on rainfall and to compare the rainfall downwind and upwind of the Tel-Aviv area.

The rainfall in the area is characterized by a long dry summer, a very sporadic and intense shower in autumn, widespread low-intensity rains in winter and more sporadic and intense rains mainly inland in spring (Sharon and Kutiel, 1986; Kutiel, 1991). The main rainfall producing cloud system in Israel are predominantly associated with cold, low pressure systems affecting the Eastern Mediterranean (Gagin and Gabriel, 1987). The study of the polar outbreak into the Levant and Eastern Mediterranean (Sarroni et al. 1996) for the period 1983-1989 reported 72 days of polar outbreak, all of them between October-May, originating in the vast continental regions of Asia and Europe causing cold, dry and stable unique condition with higher frequency in winter months (December-February). Under these conditions, the underlying ocean results in coastal upwelling and new ocean temperatures that are cooler than zonal patterns: The subsidence air is much warmer and drier than the air that has been in contact with the sea surface and strong inversion warms at the interface of the two air masses (Hanson, 1991). This will reduce the availability of moisture flux transport and thus rainfall in the nearby coastal areas, such as in Gaza.

Most of the rainfall in the country is related to two upper air patterns. First, a 500mb trough axis oriented from northwest to southwest with southwesterly flow aloft. Second, a 500mb trough axis oriented north to south with westerly flow aloft over the country, while in the south of the country the trough is oriented from northeast to southwest and the flow aloft is northwesterly. This orientation has the longest sea track with predominate rainfall (Zangvil and Drulan, 1990).

Gaza weather station is located in the southeastern corner of the Mediterranean basin (Figure 1).It is about 50 m from the shoreline and with

10 m above the sea level. As Gaza station located on the coastal plain, the localized effects on rainfall are small (Sharon and Ronberg, 1987).

Figure 1 : Location of Gaza

The area of and around Gaza is affected by different synoptic conditions to those of the northern and southern parts of the country. The area lies in southern limit of the influence of the depressions moving east from Cypress, and influenced by depressions moving southeastward, Benard cells, coastal front and by Gaza low (Kutiel, 1985, and Sharon, 1978), which can extend as far as the central Negev (Kutiel, 1982). Because the coastline bends sharply toward the west near latitude 31^{o}N; the orientation of synoptic disturbances, responsible of precipitation to north and south of this line; is markedly different (Zangvil and Drulan, 1990). The area from Be'er Sheva to Mediterranean coast underwent major changes in settlement and irrigation (Ben-Gai, et al. 1993).

Comparing the isohyet maps of 1951-1980 and the 1931-1960, Goldreich (1987) showed that the former period tends to display a zonal direction, and the latter manifest a more meridional orientation long periods of below average rainfall culminating in what is termed drought. This constitutes one of the most series hazards to the economy and so to the well being of large segments of the population (Gordon, 1993). Changing precipitation patterns and their impact on surface water resources is an important climatic problem facing society today, especially as it relates to potential global change (Keim et al. 1995). The timing of fluctuation in precipitation may have adverse implication at a variety of stages in crop growth, particularly seed germinating, reduction of growth seasons, failure of the crop to ripen and destruction of standing plants immediately prior to harvesting (Waylen and Henworth, 1996). However, some mechanisms behind these observed climatic fluctuations are still poorly understood (Keim et al. 1995).

Climate variability, especially the variability of rainfall is of most interest to the region, since it lies in the fringe of the hottest and largest deserts in the world: the Sahara to the southwest and the Arabian Desert to the east. There is a great political conflict over water resources of the region, but there is a promising scope in the future for cooperation to redistribute water between the adjacent countries to resolve their water deficiencies needed for economic and urbanization growth**.** (Rowely, 1999)

Studies indicate that rainfall fluctuation and trend are not regional but global in nature. Precipitation trend may provide additional indicator in the evaluation of CO_2 induced climatic change (Amanatidis et al. 1993; Druyan et al. 1995). A range of general circulation models (GCMs) simulation indicated a small increase in annual rainfall up to 10% under doubled CO_2 (Bradely et al.1987; Rowntree 1990). However GCM projection on precipitation may be more in error than those of temperature particularly on regional scales (Gan, 1995), these small changes in rainfall can result in large change in the frequency and intensity of wet and dry years (Wigley and Jones 1987; Joubert et al. 1996); The GCMs is widely used to provide estimate of doubled CO_2 induced climatic change, but are unreliable at stimulating regional rainfall distribution, therefore modelled changes in the total rainfall resulting from a doubling of atmospheric CO_2 should be interpreted with caution (Joubert, et al. 1996).

The overall trend in temperature has been upward over the last 100 years and mostly occurred since mid 1970 (Houghton et al. 1990), and higher temperature occurred in early 1980 and continues into 1990 which were 1995 recorded the warmest years since 1861 (Komuscu, 1998).

The main purpose of this research is to show if the rainfall in Gaza reflects the Mediterranean rainfall variability and the drought condition that prevail in this region particularly in the Eastern Mediterranean.

Data and Methodology

Daily rainfall data of Gaza is available for 32 years from October 1967 to December 1998, with continuous monthly total record. May and September are excluded from this analysis, because May was a dry month with 8 rainy days having only a total rainfall 61.4 mm and September with 3 rainy days giving a total of 2.4 mm in the whole period 1967-1998. Winter consists of December, January and February, Spring is March and April, and Autumn is October and November. Unfortunately data of atmospheric circulation are not available to researcher to relate variations of rainfall to the variations of atmospheric pressure. However there are a number of existed investigations of the relationship between circulation changes and rainfall variability over and around the area, and these will be refered to where it is appropriate.

In this study rainfall total was calculated for October to April rainy season. The monthly rainfall totals and their seasonal variation are important in defining the climate of a region and have great implication for regional climatic scenarios for a CO_2-warmed world (Yu and Neil, 1991).

Standardized anomalies (departures) or Z-score values are used extensively in different climate studies, to remove seasonal signal, to detect trend and fluctuation of many climatic elements (Jones and Conway 1997; Leite and Peixoto, 1996; Yang, 1996; Kutiel et al. 1996; Turkes 1996; Rao et al. 1995; Smith 1995; Yang and Xu 1994 and Gregory 1975).

A dry year or season may be defined when normalized deviation (Z-score) is ≤ -0.5 and extremely dry when $Z \leq -1.5$; and wet when $Z \leq 0.5$ and extremely wet when $Z \geq 1.5$ (Kutiel et al. 1996). A dry year or season may also be defined when rainfall mean is less than the mean minus one standard deviation (Parathasarthy et al.1991). Meanwhile; standardized values represented by departure index, measure how normal or unusual a particular year or event is compared to the long-term climatic average; large departure either well above or well below from the normal, represent unusual year (Suckling, 1998).

The term drought in most cases refers to a period of months within the annual time from what cumulative precipitation is considerably below average, and the precipitation anomalies may express differences from the long-term mean (Gordon, 1993). In this study the simple statistical analysis of cumulative standardized departure is used to study the Gaza rainfall, its fluctuations, variability and trend in the period 1967-1998. A dry year is defined when the cumulative Z-values of the rainfall total are below the long-term mean.

Monthly Rainfall

Table (1) shows the monthly, seasonal, annual means, standard deviation (SD), percentage of total rainfall and the C.V. Highest monthly mean rainfall occurs in January and December, while the lowest monthly mean occurs in April. The highest SD occurs in the wettest month from November to February, which means that rainfall variability is high in these months, with the highest annual percentage, particularly January and December.

Figure (2) shows the cumulative Z-scores of the monthly rainfall from October to April 1967-1998. October rainfall shows below average rainfall from mid 1970s to late 1980s culminating in sever drought year at 1985, and above average rainfall from 1967 to mid 1970s and from late 1980s to the present. Ben-Gai et al. (1993) shows a well-defined trend in October rainfall, most pronounced in 1963-1984, exceeding 300% with respect to 1938-1962 at station between Be’er Sheva and the Mediterranean coast. In 1950-1980 October was characterized by anomalous northerly flow over the Eastern Mediterranean (Kutiel, 1991).

November shows downward trend from mid 1970s to early 1990s with severe drought in 1985 Similar to October. December shows different characteristics pattern to those of October and November, with below average rainfall until mid 1970s and from early 1980s to early 1990s. The months November and December show relatively similar pattern of increasing rainfall at the end of the 1990s.

Figure2: Monthly Rainfall cumulative Anomalies October– April 1967- 1998

In January, the dry condition lasted from the 1960s to late 1990s, with few intervening wet years. The months of November, December and January are characterized by decrease strength of the Siberian high in 1950-1980 (Sahsamanoglou et al. 1991); The flow over Israel was zonal, but more meridional in January, and the latitudinal gradient of rainfall over Israel should be enhanced (Kutiel, 1991). The 1000/500hpa layer over the Mediterranean in January was -4^{o}C cooler than the corresponding layer over the Atlantic Ocean, with strong negative SST in the Eastern Mediterranean (Mackrogiannis and Sahsamanoglou, 1992). In January the main branch of the Atlantic westerlies shift southward by 6^{o} of latitude to its most southerly mean position (Jacobeit 1987). The zonal index during 1899-1990 (Kozuchowski 1993) showed that the highest annual values which aoccurred in January-December. Saaroni et al. (1996) found that, in December, average cyclone track is more toward the southern part of the Mediterranean region but during the later winter month the trajectories tend northward toward Turkey.

February has a dry condition from the beginning of the record.It reaches its highest dryness from late 1970s to late 1980s, and shows above average rainfall from 1992 and then declined again. So the dry condition from the beginning of the record lasted to early 1990s. In this month the anomaly flow over Israel was easterly and southeasterly and rainfall decreased in 1950-1980 (Kutiel, 1991). The months from November to February of the period 1950-1988 is characterized by decrease values of the Siberian high pressure (Sahsamanoglou et al. 1991).

March shows similar rainfall characteristics to February from the beginning to the end of the period. It shows a consistent below average rainfall in the whole series with dramatic variation, which contradict the increasing rainfall in March found in Ben-Gai et al (1994).

April shows its own different rainfall characteristic with above average rainfall over the whole period. However wetter conditions prevail throughout the period, a high/low values is also shown. There is a consistent upward trend reachs its peak in 1977. From then, there was a general decline of rainfall to the 1998, with alternating high and low values. From mid-March to late April there is a spell of southwest advancing Atlantic westerlies, with much more broadened trough axis that causes reactivated rainfall conditions above Israel (Jacobeit 1987). The pressure over the Sahara desert reduced in 1950-1980 relative to 1931-1960, contributing to increase late season rainfall. April mean sea level pressure anomalies over the region was favorable for enhanced rainfall in the Eastern Mediterranean in 1950-1980 and characterized by negative anomaly over Sahara desert and positive anomaly over Europe-Siberian section (Kutiel, 1991).

Comparing the rainfall for the perios 1931-1950 and 1951-1980 demonstrated that in December the rainfall shows increasing variability in the latter period and another decrease of C.V in March and April denoting a more stable rainfall regime in that period (Kutiel, 1991). There was an increase in the surface pressure in September over the Eastern Mediterranean in 1951-1980 which signify an increase in divergence. This explains the decreased rainfall in September-October (Kutiel, 1991). He concluded that the rainfall in January-February shows general decrease in 1951-1980, while the average rainfall for March-April shows a general increase (only shown in April Figure 2).

However, Kutiel (1985) found that the main rainy season becomes longer southward in the region, and the time of occurrence of the minimum rainfall activity, which is the same over the whole country, is attributed to the location and direction of the Jet-stream over the country.

Seasonal Rainfall

The Eastern Mediterranean is characterized by a regular long dry period during the summer (Legates and Wilmott 1990), and a random dry/wet periods of various length during other seasons (Kutiel et al. 1996). Annual rainfall distribution appears to be periodic in nature, with a peak values during winter and zero in summer. This periodicity is a general feature of the whole of the country, and there are considerable differences in isohytes for various winter months between coastal plain and the mountain areas (Goldriech and Manes, 1979).

Autumn contributes 21.5% of rainfall due to low rainfall total in October (Table 1), with SD greater than Spring, which mean that Autumn is characterized by greater rainfall variability than those of Spring. Autumn rainfall is very sporadic in Israel giving only 10-20% of the total amount, very intense rainfall occurred, because the air mass coming from relatively warm sea is very unstable when reaching the coastal region.

Figure (3) shows the seasonal rainfall patterns. Autumn shows similar characteristics annual trend to those of November, with downward trends from mid 1970s to late 1980s which reach its lowest values in 1985 and become above average from early 1990s onward. Winter has the highest mean total rainfall, SD and percentage rainfall confirming the highest variability and the important of winter rainfall. Winter, the main rainy season, contributes 67% of the annual total with lowest C.V. (see Table 1). Winter season shows a stationary negative trend from the beginning of the

Figure 3: Seasonal Rainfall Cumulative Anomalies 1967-1998

record to early 1990s, with lowest values in 1986. This may be related to the increase of the zonal index during 1970s and 1980s when it reaches its maximum values in 1990, while low values was observed in 1960s (Kozuchowski, 1993). Air masses in winter coming from the sea are more stable, since there are smaller temperature differences between the sea and the country, with less frequent high intensity, and cold front are the main synoptic systems producing rainfall associated with Cypress depression.

Spring the last wet season contributes 11.6% and lowest S.D. Drought conditions which start from the beginning to the end of the record and reach its lowest values in 1989. Spring contributes 15-35% of annual rainfall in the whole country. The main air masses coming from the Mediterranean are relatively stable, thus sporadic rainfall is less frequent than in autumn. The Red Sea trough, which is an extension of the Sudanian low is quite active in spring, causing occasionally high intensity rainfall and flood, when it moves northward (Kutiel, 1982). However southerly flow in the Eastern Mediterranean means dry air masses moving from the Sahara desert.

Autumn, winter and spring show similar rainfall patterns of severe drought conditions in mid 1980s (see Figure 3).

Annual Rainfall

Figure (4) shows the annual rainfall pattern. Rainfall decreases from the beginning of record and becomes progressively severe to its lowest values in 1985 which is the most extreme dry year with intervening wet years in 1990s similar to winter pattern. The highest total of 896mm recorded in 1991-1992 followed by 1995 and the lowest is 189mm recorded in 1985-1986. The mean annual rainfall for the period 1967-1998 is 413.5mm and C.V. of 38.8%. The rainy period of 1998-1999 is the driest year since 1967 (164.7mm). Sahsamanoglou et al. (1991) found continuous decreases in the central pressure of the Siberian high since 1970s related to continuous rise of the 1000-500hpa layers. Maheras (1988) found a dry period in 1980s. There is a concordance between dry years and the shift of the Azores high to the east during the 1980s dry period and the intensification of the Azores high which coincide with a new period of low precipitation (Esteban-Parra et al. 1989).

The last dry sequences in Jerusalem since 1970s, mainly in winter, is due to the weakening of the northern meridional flow, which in turn related to the continuous weakening of the Siberian high in the last 30 years (Kutiel 1991 and Hanson 1991). Negative anomalies of mean sea level pressure over the Mediterranean (Makrogiannis and Sahsamanoglou, 1990) coincide with rainy period, and positive anomalies during 1970-1980 correspond to dry period in Gaza. Esteban-Parra et al. (1998) showed that the 1980s have a very high index, particularly during winter, which can be related to the lower precipitation. High zonal index represent strong westerlies, and low index is a meridional circulation (Striem, 1981); The analyses of rainfall in

Jerusalem showed that the annual rainfall decreased by about 100 mm, which coincide with large pressure difference of +3.1mb between 1861-90 and 1931-1960 over western Soviet Union (Striem, 1981).
The Levant and most of the Eastern Mediterranean basin are influenced by the westerly flow which increases from north to south in the period 1983-1988. The largest 300hpa gradient increases occurred at latitude 30^{o}N in the 1970s and early 1980s, and the maximum increase in the westerly wind component can be derived around 30^{o}N at roughly 1m^{s-1} in 1981-1985 (Weber 1994; Sarroni et al 1996). Weber (1990) found a remarkable large positive departure of 300/1000mb tropospheric temperature over the Middle East and concluded that in the low latitude 10-30^{o}N the troposphere was considerably warmer in 1977-1986 and ocean being colder and the continent being warmer in mid-latitude 40-60^{o}N. The mean temperature of the surface-500hpa shows positive trend over the Mediterranean, which is a result of small change of the circulation during the period. This is also confirmed by the increase of atmospheric pressure over the sea surface and by the decrease of cold advection at the 500hpa.

The annual precipitation anomalies for the global land area (1900-1993) expressed as a percentage departure from 1951-1980 mean showed a persistent downward negative trend from early 1970s onward, and for Northern Hemisphere tropical area from mid-1960s onward (Hulme, 1995, Figures 4 and 6). During the 1980s we had the highest global mean temperature values of the last 90 years (Makrogiannis and Sahsamanoglou, 1992). The period of increase of those values began in the mid 1970s; the 1980s started with a series of world-wide drought affecting the arid realm from Australia to South America (Agnew 1989). The annual rainfall trend shows similar rainfall trend to those of the seasonal values, which confirm that the dryness of the rainfall in Gaza is true and consistent with the seasonal patterns.

Discussion and Conclusion

The arid and semi-arid regions face extreme temporal variability with dry and wet periods which may extend for several years (Brendtsson, 1998). Dry conditions become dominant since 1970s and early 1980s over most of Turkey Istanbul have had significant difficulties in supplying enough freshwater for daily use since mid 1980s (Turkes, 1996). Similar drought conditions and implication are seen in Gaza in the same period but have started earlier in the late 1960s and become most severe in 1980s, which may be attributed to negative SST anomalies found in the Eastern Mediterranean (Turkes, 1996).

Within the last century, the rainfall in Israel has decreased by one fifth, while winter grew warmer by 1°C. (Gagin and Gabriel 1987). This increase of the tropospheric air temperature has been generally related to increasing the concentration of CO_2 (Weber1990; Schonwise and Malcher 1987; Rowntree 1998; Wigley and Jones 1987; Jones et al. 1986).

In Gaza the months from November to February experienced dry conditions from 1960s to early 1990s with intervening few wet years of the 1970s in December and January. October only shows dry conditions in mid 1980s while March and February are characterized by severe dry conditions. Only April shows wet conditions throughout the whole period.

Winter experienced continuing drought conditions despite a weak recovery in early 1990s. Autumn was dry in mid 1970 to late 1980s and above average in mid 1960s to early 1970s. Spring was dry all over the period. Annual rainfall shows dry conditions with wet years in early 1990s. So winter, spring and Annual rainfall all have drought conditions to 1990s.

The repeated drought in recent years have given impetus to statistical studies of the precursor role of SST in upsetting the balance of continental and marine rainfall (Yang 1996). However, the relationship between SST anomalies and rainfall is not a direct, caused link, but rather both are related to the circulation and specially the wind anomalies (Drosdowsky, 1993).

The increase of polar continental outbreak in the Eastern Mediterranean with dry and stable unique condition (Sarroni et al. 1996) should be attributed to the increase in frequency and strength of northerly wind in the region (Metaxas et al. 1991), coupled with pronounced cold SST in the Eastern Mediterranean particularly during 1960-1970s (Repapis and Philandars 1988; Metaxas et al. 1991; Sahsamanoglou and Makrogiannis 1992; Makrogiannis and Sahsamonoglou 1992; Turkes et al.1995; Zhu and Houghton 1996). The resulting decline of SST reduced the large-scale convective activity, instability and the supply of heat and moisture to upper level (Hunt and Davies 1997), hence reducing the potentiality of atmospheric mechanism producing rainfall over the Levant and the dryness continues in Gaza.

Years with lower than normal SST tends to be more cloudy (Reddaway and Bigg 1996). These cloud have the potential to exert positive feedback in the climate systems (Parker 1989; Reddawy and Bigg 1996), which may affects the intensity of the extreme atmospheric pressure or pressure gradient and the atmospheric waves distribution in turn modifies the circulation and consequently the patterns of moisture flux and divergence that ultimately determine the rainfall rates (Druyan 1991 and Moron et al. 1995).

Ben-Gai et al. 1993; Kutiel 1991 showed that most of the increase of rainfall amount in Israel is related to daily amount rather than to the number of rainy days, similar conditions can be seen in Gaza (see Table 2). Kutiel (1985) concluded that the cycle of the length of dry spell is not a random phenomenon, but it is a general phenomenon which cover almost all the country, or may be a phenomenon related to general factors affecting the rainfall regime in all the Eastern Mediterranean.

Figure 4. Annual Rainfall Cumulative Anomalies 1967-4998

Rainfall in Greece reduced from about 750mm in 1920s to about 600 mm in the last decades (Amanatidis, et al. 1993). Dry sequences in Jerusalem started in 1944-1945 and remained very sever until 1961-1962 with short humid episode 1962-1970 and since then dry sequences continued where the latest was the most severe (Kutiel et al. 1996). This is consistent to those found in Gaza. The dry conditions in Jerusalem since 1970s, mainly in winter, are associated with south easterlies prevailing from the Arabian desert and to weakening of the northern meridional flow which in turn is related to the continuous weakening of the Siberian high in the last 30 years (Kutiel et al. 1996). In addition the center of the Azores anticyclone has a high frequency from 1950 until 1980 in the eastern section of the Atlantic, and the period 1968-1980 is characterized by high values of the annual central pressure of the Azores anticyclone (Sahsamanoglou, 1990) with an increase of northerly continental flow over the Eastern Mediterranean. This cold wind cools the Eastern Mediterranean and negative temperature occurs (Corte-Real et al. 1995) and the cold continental northerly outbreak is responsible for depleting heat storage of the sea (Flamant and Pelan 1996).

The pressure gradient between the ridge in the north and the Red sea trough in the south means that the zonal index is negative, causes quite strong easterly wind in the Levant in the period 1982-1988 and the tropospheric thicknesses between 10^{o}N-80^{o}N was 38gpm higher, with a remarkable increase of gradient over the Middle East (Weber, 1990; Makrogiannis et al. 1991; Saaroni et al. 1996). This is consistent with the dryness of the same period in Gaza, where easterly is a dry wind throughout the year.

However, the increase trend in precipitation may be an indication of urban effects on precipitation enhancement in the downwind area (Goldreich and Manes 1997; Amanatidius et al. 1993), and the effect of intensive urbanization in the downwind of coastal plain (Goldriech, 1987). Whereas station in the upwind region showed an apposite decreasing trend (Goldrieh and Manes 1979), similar to decreasing rainfall in Gaza which is located in the upwind of the Gaza city near the shoreline, where urbanization has no effects in the rainfall of Gaza.

The increase of rainfall in southern Israel (Bin-Gai, et al. 1994) was related to the increase in land used and to the global change in SST starting in the early 1960s. The increase in Gaza strip was around 20-25% (Figure 4). This increase may not be true. It could be related to decrease rainfall in northern stations, such as the decrease rainfall of Jerusalem reported above by Striem, however the study of 700hpa (Kutiel and Kay. 1992) showed that the anomaly flow associated with centre of positive differences in the north and negative in the south is generally easterly over the Mediterranean such anomaly flow does not suggest an increase frequency of cyclonic passage in the westerly, hence drier than normal conditions in Gaza.

Wilby (1993) found a consistent upward increasing trend of cyclonic types from 1950 to 1991 in Britain and Northwest Europe which suggest adecrease penetration of cyclones over the Mediterranean basin and hence less rainfall. However, the Eastern Mediterranean climate is subjected to competing influence from Southern Asia, Africa and Siberia (Reddaway and Bigg 1996).

Moreover the weakening of the Siberian high means that fewer depressions ate moving in the Mediterranean in winter. Atmospheric circulation over the Mediterranean has exhibited significant changes during recent years (Makrogiannis et al. 1991; Sahsamanoglou and Makrogiannis 1992), with an increase of atmospheric pressure which began in 1960 over large parts of the Mediterranean, due to northward shift of depression over the Mediterranean area, and a negative surface-500hpa temperature over the southeast of the Mediterranean. In addition there was a delay in the development of the high pressure over Siberia in 1950-1980 (Kutiel 1991). These facts could result in decrease penetration of mid-latitude depressions in the area and more dry period is noticed in Gaza.

Nevertheless an important fluctuation in precipitation have occurred over large regions and precipitation trends may provide an additional indicator of the evaluation of greenhouse gas induced climate change (Esteban-Parra et al. 1998). However, world-wide precipitation changes expected by the numerical models with enhanced atmospheric CO_2 have not yet been unambiguously identified in the observation (Parker, 1989). Meanwhile precipitation is a difficult climate variable to predict spatially (Hulme, et al. 1995). It is perhaps not an exaggeration to say we don't yet know how wet our planet is nor how wet or dry it may become (Hulme 1995).

The dry conditions of 1968-1985 in Greece; of 1980s in Spain and Turkey; the continuing of drought in Jerusalem since 1970s and in Gibralter since the 1960s are in concordance with the drought conditions found in Gaza.

Table 1. Monthly, seasonal and annual mean, S.D., total percentage rainfall and C.V.

	Mean	SD	%	CV
October	21.0	27.1	5.2	129.0
November	65.3	78.7	16.3	120.5
December	95.8	76.5	23.9	79.9
January	109.8	71.6	26.6	65.2
February	68.8	57.4	16.5	83.4
March	38.5	27.7	9.3	71.7
April	9.1	11.6	2.2	127.5
Autumn	86.3	83.6	21.5	96.9
Spring	47.9	28.9	11.6	60.9
Annual	413.5	160.8		38.8

Table 2. sequences of heavily rainy days in Gaza.

Events	**Dates**	**Rainfall**	**Events**	**Dates**	**Rainfall**
(1)	3/1/1990	41.0	(4)	15/12/1992	35.3
	4/1/1990	69.0		16/12/1992	79.6
	Total	**110.0**		17/12/1992	25.0
(2)	28/11/1991	24.8		Total	**139.9**
	29/11/1991	30.2	(5)	23/11/1994	65.2
	30/11/1991	118.0		24/11/1994	36.2
	1/12/1991	130.0		Total	**101.4**
	2/12/1991	81.6	(6)	4/1/1996	45.4
	3/12/1991	25.8			
	4/12/1991	16.8			
	Total	**427.2**			
(3)	21/1/1991	28.7			
	22/1/1991	34.7			
	23/1/1991	35.2			
	24/1/1991	18.5			
	25/1/1991	10.5			
	Total	**127.6**			

References

- Agnew, C. T. 1989. Sahel drought: Meteorological or agriculture. *Int. J. Climatil.*, 9:371-382.
- Amanatidis, G. T., Paliatsos, A. G., Repapis, C. C. and Bartzis, J. G. 1993. Decreasing precipitation trend in the Marathon area, Greece. *Int. J. Climatol.*, 13:191-201
- Ben-Gai, T. Bitan, A., Manes, A. and Albert, P. 1993. Long-term change in October rainfall patterns in Southern Israel. *Theor. Appl. Climatol.*, 46:209-217.

- Ben-Gai, T. Bitan, A., Manes, A. and Albert, P.1994. Long-term change in annual rainfall patterns in Southern Israel. *Theor. Appl. Climatol*., 49:59-67.
- Bradley, R. S., Diaz, H. F., Eischfid, J. K., Jones, P. D., Kelly, P. M., and Goodess, G, M. 1987. Precipitation fluctuation over Northern Hemisphere land area since the mid-19th century. *Science* 237:171-175.
- Brendtsson, R. 1989. Topographical and spatial precipitation patterns in Tunisia. Int. J. Climatol., 9:357-369.
- Corte-Real, J. Zhang, X. and Wong, Y. 1995. Large-scale circulation regimes and surface climate anomalies over the Mediterranean. *Int. J. Climatol*. 15:1135-1150
- Drosdowsky, W. 1993. The analysis of Australian seasonal rainfall anomalies. 1950-1987 II: Temporal variability and teleconnection patterns. *Int. J. Climatol*., 13:111-149.
- Druyan, L. M. 1991. Modeling the differential impact of 1984 and 1950 sea surface temperature on Sahel rainfall. *Int. J. Climatol*., 11:367-380
- Druyan, L. M., Shah, P., Lo, K-K., Marengo, J. A. and Russel, G. 1995. Impact of model improvement on general circulation model sensitivity to sea-surface temperature forcing. *Int. J. Climatol.,* 15:1061-1086.
- Esteban-Parra, M. J., Rodrigo, F. S. and Castro-Diez, Y. 1998. Spatial and temporal patterns of precipitation in Spain for the period 1880-1992. *Int. J. Climatol*., 18:1557-1574.
- Flamant, C. and Pelan, J. 1996. Atmospheric boundary-layer structure over the Mediterranean during Tramontane event. *Q. J. R. Meteorol. Soc.,* 122:1741-1778.
- Gan, T. 1995. Trends in air temperature and precipitation for Canada and North-Eastern USA. *Int. J. Climatol.* 15:1115-1134
- Gagin, A. and Gabriel, K. R. 1987. Analysis of recording rain gage data for the Israeli II experiment. Part 1: effects of cloud seeding on the component of daily rainfall. *J. Climate and Appl. Meteorol*., 26:913-921.
- Goldreich, **Y.** 1987. Temporal changes in the spatial distributions of rainfall in the Central coastal plain of Israel. *In Recent climate change-A regional approach*, ed. S. Gregory, 116-124. London: Belhaven.
- Goldreich, Y. and Manes, A. 1979. Urban effects on precipitation patterns in Greater Tel-Aviv area. *Arch. Met. Geoph. Biockl., Ser. B*., 27:213-234.
- Gordon, A. M.1993. The random nature of drought: Mathematical and physical cause. *Int. J. Climatol.,* 13:497-507.
- Gregory, S. 1975. On the delimitation of regional patterns of recent climatic fluctuations. *Weather* 30:276-287.

- Hanson, H. P. 1991. Marine stratocumulus climatologies. *Int. J. Climatol*., 11:147-167.
- Houghton, J. T., Jenkins, G. J. and Ephraums, J. J. (eds.) 1990. *Climatic change*. *The IPCC scientific assessment*. Cambridge University Press. 365pp**.**
- Hulme, M. 1995. Estimating global change in precipitation. *Weather* 50:34-42.
- Hulme, M., Conway, D., Jones, P. D., Jiang, T., Barrow, E. M., and Turney, C. 1995. Construction of a 1961-1990 European climatology for climatic change modeling and impact applications*: Int. J. Climatol.,* 15:1333-1363.
- Hulme, M., Conway, D., Jones, P. D., Jiang, T., Barrow, E. M., and Turney, C.1991. Simulation of USA drought of 1988. *Int. J. Climatol*., 11:629-644.
- Hunt, B.G. and Davies, H. L. 1997. Mechanism of multi-decadel climatic variability in a global climatic model. Int. J. Climatol., 17, 565-580.
- Jacobiet, J. 1987. Intra-seasonal fluctuation of mid-tropospheric circulation above Eastern Mediterranean. *In Recent climatic change-A regional approach,* ed. S. Gregory, 90-101. London: Belhaven.
- Jones, P. D., Barper, S. G.,Bradley, R. S. Diaz, H. F., Kelly, P. M. and Wigley,T. M. L. 1986. Northern Hemisphere air temperature variations. *J. Climate and Appl. Meteorol*., 25:161-179.
- Jones. P. D. and Conway. D. 1997. Precipitation in the British Isles: An analysis of area-average data updated to 1995. *Int. J. Climatol*., 17:427-438.
- Joubert, A. M., Mason, S. J. and Galpin, J. S. 1996. Drought over Southern Africa in a doubled CO_2 climate*. Int. J. Climatol.,* 16:1149-1156
- Keim, B. D., Faiers, G. E., Muller, R. A., Grymess, J. M. and Rohli, R. V. 1995. Long-term trends of precipiation and runoff in Louisiana, USA. *Int. J. Climatol*., 15:531-541.
- Komuscu, A. U. 1998. An analysis of the fluctuation in the long-term annual mean air temperature data of Turkey. *Int. J. Climatol.,* 18:199-213.
- Kozuchowski, K. M. 1993. Variation of the hemispheric zonal index since 1899 and its relatiomship with air temperature. *Int. J. Climatol*., 13:853-861.
- Kutiel, H. 1982. Spatial coherence of monthly rainfall in Israel. *Arch. Met. Geoph. Biockl., Ser. B*. 31:353-367.

- Kutiel, H.1985. The multimodality of rainfall course in Isreal as reflected by the distribution of dry spells. *Arch. Met. Geoph. Biockl. Ser., B*., 36:15-17.
- Kutiel, H.1990. Variability of factors and their possible application to climatic studies. *Theor. Appl. Climatol.,* 42:169-175.
- Kutiel, H.1991. Recent spatial and temporal variations in mean sea level pressure over Europe and the Middle East and their influence on the rainfall regime in the Galilee, Israel. *Theor. Appl. Cl*imatol., 44:151-166.
- Kutiel, H. and Sharon, D.1981. Diurnal variation in the spatial structure in the Northren Negev Desert, Israel. *Arch. Met. Geoph. Biokl., Ser. B.* 29:239-243.
- Kutiel, H. and Kay, P. A. 1992. Recent variations in 700hpa geopotential heights in summer over Europe and Middle East and their influence on other meteorologiacl factors. *Theor. Appl. Climatol.,* 46:99-198.
- Kutiel, H. Maheras, P. and Guika, S. 1996. Circulation and extreme rainfall conditions in the Eastern Mediterranean during the last century. *Int. J. Climatol.,* 16:73-92
- Legates, D. R. and Willmott, CJ**.** 1990, Mean seasonal and spatial variability in gauge-corrected global precipitation*. Int. J. Climatol.,* 10:111-127.
- Leite, S. M. and Peixoto, J. P. 1996. The autoregressive model of the climatological time serie: An application to the longest time series in Portugal. *Int. J. Climatol*., 16:1165-1173.
- Maheras, P. 1988. Change in precipitation condition in Eastern Mediterranean over the last century. *Int. J. Climatol.,* 8:179-189
- Maheras, P. and Kolyva-Machera, F. 1990. Temperature and spatial characteristics of annual precipitation over the Balkans in the Twentieth century. *Int. J. Climatol*., 10:495-504
- Makrogiannis, T. J. and Sahsamanoglou, H. S. 1990. Times variation of the mean sea level pressure over the major Mediterranean area. *Theor. Appl. Climatol*., 41:149-156.
- Makrogiannis, T. J. and Sahsamanoglou, H. S.1992. Analysis of mean temperature variation at 1000/500hpa layer over Europe, 1945-1988. *Theor. Appl. Climatol*., 45:193-200.
- Makrogiannis, T. T., Sahsamanoglou, H. S., Flocas, A. A., Bloutosos, A. A. 1991. Analysis of monthly zonal index values and long-term changes of circulation over the North-Atlantic and Europe. *Int. J. Climatol.,* 11:493-503.

- Metaxas, D. A., Bartzokas, A. and Vitsas, A. 1991. Temperature fluctuation in the Mediterranean area during the last 120 years. *Int. J. Climatol*., 11:897-908.
- Moron, V., Bigot, S. and Roucou, P**.** 1995. Rainfall variability in subequatorial America and Africa and relationship with sea surface temperature modes (1951-1990*). Int. J. Climatol*., 15:1297-1322.
- Parker, D. E. 1989. Observed climatic change, and greenhouse effects. *Metorol. Magazine*, 118:128-131
- Parthasarathy, B. Kumar, R. K, and Deshpande, V. R. 1991. Indian summer monsoon rainfall and 200mbr meridional wind index: Application for long-term prediction*. Int. J. Climatol.,* 11:165-176.
- Rao, V. B., Hada, K. and Herdies, D. L**.** 1995. On the severe drought of 1993 in Northeast Brazil. Int. J. Climatol., 15:697-704.
- Reddaway, J. M. and Bigg, G. R. 1996. Climatic chamge over the Mediterranean and links to the more general atmospheric circulation. *Int. J. Climatol*., 16:651-661
- Repapis, C. C. and Philandras. C. M. 1988. A note on the air temperature trends of the last 100 years as evidenced in Eeastern Mediterranean time series. *Theor. Appl. Climatol*., 39:93-97.
- Rowely, G. 1999. The tragedy of the common water: Towards the deepening crisis within the Jordan basin. *The Arab World Geographer* 2:26-40.
- Rowntree, P. R. 1990. Estimates of future climatic change over Britain, Part 2: Result. *Weather* 45:79-89.
- Rowntree, P. R..1998. Global average climate forcing and temperature response since 1750*. Int. J. Climatol.,* 18:335-377.
- Sahsamanoglou, H. S. 1990. A contribution to the study of action centers in the North America*. Int. J. Climatol*., 10:247-261
- Sahsamanoglou, H. S. and Makrogiannis, T. J. 1992. Temperature trends over the Mediterranean regions, 1950-88. *Theor. Appl. Climatol*., 45:183-192
- Sahsamanoglou, H. S., Makrogiannis, T. J. and Kallimopoulos, P. D. 1991. Some aspect of the basic characteristics of the Siberian anticyclone. *Int. J. Climatol*.,11:827-839.
- Sarroni, H., Bitan, A. Alpert, P. and Ziv, B. 1996. Continental Polar outbreaks into the Levant and Eastern Mediterranean. *Int. J. Climatol*., 16:1175-1191.
- Schonwise, C-D. and Malcher, J. 1987. The CO_2 temperature response. A comparison of the result of general circulation models with statistical assessments. *J. Climatol*., 7:215-229.

- Sharon, D**.** 1978. Rainfall field in Israel and Jordan and the effect of cloud seeding on them. J. *Appl. Meteorol.,* 17:40-48.
- Sharon, D. and Kutiel, H**.** 1986. The distribution of rainfall intensity in Israel, its regional and seasonal variations and its climatological evaluations. *J. Climatol.,* 6:277-291
- Sharon, D. and Ronberg, B**.** 1987. Intra-annual weather fluctuation during the rainy season in Israel, *In* R*ecent climatic change-A regional approach,* ed. S. Gregory, 102-115.London: Belhaven
- Smith, K.1995. Precipitation over Scotland, 1757-1992: Some aspects of temporal variability. *Int. J. Climatol*., 15:543-556
- Striem, H. L. 1981. Climatic fluctuation in Israel viewed through rainfall regimes. *Arch. Met. Geophs. Biockl., Ser., B*., 29:357-364.
- Striem, H. L.1991. Climatic fluctuation in Israel viewed through rainfall regime. Arch. *Met. Geoph. Biokl. Ser., B*., 29:357-364.
- Suckling, P. W. 1989. Application of climate departure index to the study of freeze points and growing season in the South-Eastern United States. *Int. J. Climatol.,* 9:383-394.
- Turkes, M. 1996. Spatial and temporal analysis of annual rainfall variations in Turkey. *Int. J. Climatol.,* 16:1057-1076.
- Turkes, M. Sumer, U. M. and Kilic, G. 1995. Variations and trends in annual mean air temperature in Turkey with respect to climatic variability. *Int. J. Climatol*., 15, 557-569.
- Waylen, P. and Henworth, S. 1996. A note on the timing of precipitation variability in Zimbabwe on relation to the southern oscillation. *Int. J. Climatol*., 16:1137-1148.
- Weber, G-R. 1990. Tropospheric temperature anomalies in the Northern Hemisphere 1977-1986. *Int. J. Climatol.,* 10:3-19.
- Weber, G-R. 1994. Seasonal and regional 300hpa heights, 300-1000hpa thicknesses and associated 300hpa zonal flow change in Northern Hemisphere between 1976 and 1990. *Int. J. Climatol*., 14:751-758.
- Wheeler, D. and Martin-Vide, J. 1992. Rainfall characeristics of mainland Europe's mostly southerly stations. Int. J. Climatol. 12:69-76.
- Wigley, T. M. L. and Jones P. D. 1987. England and Wales precipitation: A discussion of recent changes in variability and update to 1985. *J. Climatol.,* 7:231-246.
- Wilby. R. L. 1993. The influence of variable weather patterns on river quantity and quality regimes. *Int. J. Climatol*., 13:447-459.
- Yang, S. 1996. ENSO-summer monsoon association and seasonal-interannual prediction. *Int. J. Climatol.,* 16:125-134.

- Yang, S. and Xu, L. 1994. Linkage between Eurasian winter snow cover and regional Chinese summer rainfall. *Int. J. Climatol*., 14:739-750
- Yu, B. and Neil, D. T. 1991. Global warming and regional rainfall: the difference between average and high intensity rainfall. *Int. J. Climatol*., 11:653-661
- Zangvil, A. and Drulan, P. 1990. Upper air trough axis orientation and the spatial distribution of rainfall over Israel. *Int. J. Climatol*., 10:57-62.
- Zhu, Y. and Houghten, D. 1996. The impact of Indian ocean SST on the large-scale Asian summer monsoon and the hydrological cycle. *Int J. Climatol*., 16:617-632.
- Propp, V. (1995) Textual Im tewention, London: Routledge. Montgomery etal (1992) , MeRae, JandVethaman,M (1999).
- Breem, S.(1990) Speech Presentation, Text 10.3 : 220-44.

Acknowledgment

My sincere thanks to Professors S. Gregory and Peter Smithson for what they have done so far. I am grateful to two anonymous referees for their helpful comment, criticism and suggestions. Thanks to my colleges at the department of geography, Islamic University–Gaza for their impetus and encouragement's.