MAJOR CLIMATE CHANGE MECHANISMS AND HOW THEY AFFECT THE MIDDLE EAST

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The Middle East and the Eastern Mediterranean were home to some of the world's oldest civilizations. They offer therefore some of the best records of past climate change over several millennia, as well as intriguing evidence of interaction between man and his environment. Records of one or more major floods, as recorded in the Epic of Gilgamesh or the Bible have been linked to the seasonal, but sometimes catastrophic floods of Mesopotamia or, alternatively and more recently, to the post-glacial flooding of the Black Sea by saline Mediterranean waters. The drying out of the Sahara during the late Holocene has led to major shifts in its populations and cultures. The cycles of drought and plenty in the Nile valley have been associated with some of the earliest climate predictions, on the one hand, and with the change of dynasties, on the other.

We present several records of climate change over the last two millennia, from the Central Mediterranean and the Nile River. First, we study a 2200-year-long, high-resolution record of foraminiferal $\delta^{18}O$ from a Central-Mediterranean sediment core. This core, from the Gulf of Taranto, is carefully dated and shows highly significant spectral components with periods of ~600, 350, 200, 125 and 11 years. Comparison and calibration of this record with previous Northern Hemisphere temperature reconstructions over the last millennium allow us to extend the latter back to 200 B.C. This extended record provides a continuous and homogeneous baseline of temperature variability over the last 2200 years; it exhibits the Medieval Optimum and Little Ice Age features, as well as a minimum around 0 A.D. Using this result, we show that the contribution of natural variability to the modern global temperature rise is of roughly 50%.

Next, we consider the historical records of the low- and high-water levels of the Nile River. These are among the longest climatic records that have near-annual resolution. There are few gaps in the first part of the records (A.D. 622–1470) and larger gaps later (A.D. 1471–1922). We apply advanced spectral methods, Singular-Spectrum Analysis (SSA) and the Multi-Taper Method (MTM), to fill the gaps and to locate interannual and interdecadal periodicities. The gap filling uses a novel, iterative version of SSA. Our analysis reveals several statistically significant features of the records: a nonlinear, data-adaptive trend that includes a 256-year cycle, a quasi-quadriennial (4.2-year) and a quasi-biennial (2.2-year) mode, as well as additional periodicities of 64, 19, 12, and, most strikingly, 7 years. The quasi-quadriennial and quasi-biennial modes support the long-established connection between the Nile River discharge and the El-Niño/Southern Oscillation (ENSO) phenomenon in the Indo-Pacific Ocean. The longest periods might be of astronomical origin. The 7-year periodicity, possibly related to the biblical cycle of lean and fat years, seems to be due to North Atlantic influences.

At this point, we turn from records of past climate variations to the mechanisms of climate variability and climate change. The Middle East and the Eastern Mediterranean are at the confluence of several climatic influences, between (i) the prevailing westerlies and hence

North Atlantic influences to the west and north; (ii) the South-Asian and Indian-Ocean monsoonal winds to the south-east; and (iii) the descending branch of the Hadley cell and the West-African monsoon to the south and west. We concentrate here on the influence of the North Atlantic Oscillation (NAO) and on a plausible oceanic mechanism for its origin and maintenance.

Oceanic variability on interannual, interdecadal, and longer time scales plays a key role in climate variability and climate change. Paleoclimatic records suggest major changes in the location and rate of deep-water formation in the Atlantic and Southern Ocean, on time scales from millennia to millions of years. Instrumental records of increasing duration and spatial coverage document substantial variability in the path and intensity of ocean surface currents on time scales of months to decades. To explain the physical processes governing the large-scale ocean circulation and its intrinsic variability, we apply systematically the methods of dynamical systems theory. This approach is proving successful for more and more detailed and realistic models, up to and including oceanic and coupled ocean–atmosphere general circulation models.

In this approach one follows the road from simple, highly symmetric model solutions, through a ‘‘bifurcation tree,’’ toward the observed, complex behavior of the system under investigation. The observed variability can be shown to have its roots in simple transitions from a circulation with high symmetry in space and regularity in time to circulations with successively lower symmetry in space and less regularity in time. This road of successive bifurcations leads through multiple equilibria to oscillatory and eventually chaotic solutions.

Key features of this approach are illustrated in detail for simplified models of the wind-driven ocean circulation. First, we obtain multiple separation patterns of a ‘‘Gulf-Stream like’’ eastward jet. These multiple equilibria are followed by subannual and interannual oscillations of the jet and of the entire basin's circulation. The 7–8-year oscillation in the models' eastward jet is compared with observations of the Gulf-Stream path and of the entire North-Atlantic circulation, oceanic and atmospheric. The physical basis of the teleconnections that lead from the NAO to the Middle East and the Eastern Mediterranean are discussed next.

Finally, we review briefly the ways that anthropogenic effects and global warming might affect a climate that is subject to marked variability, rather than being in equilibrium or near-equilibrium.

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CLIMATIC TRENDS TO EXTREMES AND REGIONAL MODELING OVER THE E. MEDITERRANEAN

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The E. Mediterranean (EM) recent climate trends include a decrease in winter temperatures and total precipitation amounts, accompanied by increases in the rainfall over the southern part of the region [IPCC, 2001] and extreme daily rainfall [Alpert et al, 2002]. Some of these features are apparently caused by the global warming effects due to a significant increase in the concentration of greenhouse gases (GHG) in the atmosphere. Role of teleconnections appears to be essential. The NAO index increase till the 90s explains the cooler and drier winters over the EM during the period [Ben-Gai et al., 2001; Krichak and Alpert, 2005b]. The fact that the south EM was not influenced by a significant and dominant rainfall decreases over the region may be explained by the positive contribution of the positive trend in occurrence of EA/WR pattern [Krichak et al., 2002; Krichak and Alpert, 2005a]. Also, increases in intensity and number of El-Nino events were found to be positively correlated to rainfall in the region [Price et al., 1998]. The rainfall increase in the southern part of Israel has possibly been affected by the local land-use changes over central to south Israel [Otterman et al., 1990, Ben-Gai et al., 1993, Perlin and Alpert, 2000]. Other Mediterranean climate connections to tropical systems like the Indian Monsoon, Saharan dust, etc. were also pointed out recently by Alpert et al (2006).

The increase of extreme rainfall over Israel in spite of decrease in rainfall totals reflects a change in the rainfall distributions. The latter is suggested to be the result of increase in tropical/mid-latitude interactions during the period. The trend has been associated with an increase in the frequency of occurrence of Red-Sea trough synoptic situations on the account of other more rain-bearing systems like the EM Cyprus Low, Alpert et al (2004). It is not yet clear if the detected trend was a consequence of the global warming or was caused by natural climate variations.

In the current study we present results of analysis of model outputs on temperature and rainfall changes over the EM and in particular Jordan River basin for 2071-2100 compared to 1961-1990 with the aim of a better understanding of possible further climate changes in the region. The investigation was performed as a part of international research efforts under GLOWA Jordan River Project (www.glowajordanriver.de) (see next section for details). The analysis is based on results of Regional Climate Modeling (RCM) simulations performed for the EU PRUDENCE project (Deque et al. 2005) at the International Centre for Theoretical Physics (ICTP) with RegCM model (Giorgi et al. 2004b). The RCM runs were driven from the lateral boundaries by data from the global atmospheric model HadAMH (Deque et al. 2005). The modeling data are available for two periods (1961-1990 and 2071-2100) with the former representing current climate and the latter the future climate conditions determined in accordance with the IPCC scenarios A2 and B2 assuming more intense and less intense GHG emission regimes during XXI century. A large scale analysis of the modeling results has been already presented by Giorgi et al., (2004a,b). In the current study we perform a more detailed evaluation of the data with the focusing on the EM region. Results of the analysis are presented and discussed in view of recent observed temperature and precipitation trends calculated for 1948-2000 based on NNRP reanalysis as well as CRU (Climatic Research Unit) of the University of East Anglia data archives [New et al. 1999, 2000].

GLOWA JORDAN RIVER Motivation

The GLOWA Jordan River project focuses on one of the most critical regions with respect to sustainable water supply. The south Eastern Mediterranean (EM) area has one of the lowest per capita water availabilities worldwide. It experiences rising water demands, while available water is gradually decreasing. Climate scenarios for the Eastern Mediterranean, based on large-scale climate models, predict further aridification and increasing variability of regional precipitation. Surface water and groundwater resources have been reduced to record lows in the recent past, mostly due to increased usage and a prolonged drought period. The upper catchment of the Jordan River (UCJR) is characterized by an elongated valley, 80 km long and 15-30 km wide, covering approximately 1600 km^2. The flow in the UCJR is continuous throughout the year. On average, the UCJR yields about $500x10^6$ m^3/y, which is about 25 percent of the total water budget of Israel. It includes the major landscape units and components of the water management system, in particular the source region for water supply in the North, and the regions receiving water from transfers mostly for agriculture, i.e. the coastal plain in the West and the semi-arid and arid desert regions in the East and South of the country. Hence, principal objectives for GLOWA Jordan River (JR) are, first, to determine the vulnerability of water resources in Israel in response to climate change, and second to develop sustainable management practices in the watershed of the Jordan River.

In next section the summer temperatures- recent observations vs. projections trends, are compared. Section 3 does a similar comparison for main winter (DJF) rainfall. Next, extreme temperatures and rainfall projections for the end of 21st century, are presented, (Sec. 4 and 5, respectively). The relationship with projected trends in the various synoptic weather systems is given in Sec 6 followed by the summary.

TEMPERATURES-SUMMER (JJA)

Figure 1 (from Saaroni et al., 2003) shows significant warming of summer (JJA-June, July, August) for 850hPa temperatures over the Mediterranean. Trend values of 1.5-4°C/100y, based on NNRP reanalysis for 1948-2000, cover the whole Mediterranean with maxima over the Western Mediterranean and North Egypt. These outstanding heating trends values are about 3-4 times larger than global trends for the last 100 years. The result may be partly affected by the changes in the observation system (Bengtsson et al., 2004). The suggestion is supported however by somewhat smaller heating trend has determined by Giorgi (2002) based on the data archive for terrestrial regions produced by CRU of the University of East Anglia, and described by New et al. (1999, 2000). The surface temperature differences from 2071-2100 compared to 1961-1990 based on ICTP regional climate modeling for two IPCC emission scenarios A2 and B2 IPCC were analyzed by Giorgi et al. (2004a,b), IPCC, (2001). The A2 scenario assumes a significant increase of the GHG concentration during the XXI century whereas the B2 is based on less extreme estimates.

Results show that for A2 scenario, the changes over the Eastern Mediterranean are about 3-5°C, while for B2 scenario the differences are only about 2.5-3.5°C. It is interesting to note that the surface heating trends projections over the sea are lower than over the surrounding land, which is just the opposite case for the observed NNRP–based temperature trends from 1948. In the observations (Fig. 2) the trends over the land are only about 0-0.8°C/100y, and in some regions (Algeria, Balkan) even negative trends are seen. Since the warming over the Mediterranean Sea is of the same magnitude, can we conclude that the warming over land is also going to accelerate in the 21st Century? Or, that the models are not doing a good job? Or maybe there are significant variations from 850 hPa to the surface? The answer is not yet clear. Additional RCM investigations of the issue are currently in process at Tel-Aviv University and will be presented separately.

RAINFALL WINTER (DJF)

The observed precipitation trends over nearly the whole Mediterranean are dominantly negative during 1948-2000 (Alpert et al., 2004 based on NNRP reanalysis). The NNRP data on precipitation are based on the model estimates and are not necessarily accurate. The results are supported however by numerous observational rain gauge-based studies e. g. Alpert et al., 2002, IPCC, 2001.

The RegCM-ICTP runs for 2071-2100 compared to 1961-1990 show large differences between scenarios A2 and B2 (Fig. 3). The black box is centered over Israel and the Jordan-River basin. In A2, most of the Eastern Mediterranean shows rainfall reduction of about 15-75 mm for DJF, which is equivalent to drops of about 10-30%. The DJF period covers most of the annual rain in the Eastern Mediterranean, and realistically reflects the annual rainfall changes, although some changes in seasonal distribution of rainfall are predicted as discussed in Sec. 5. In scenario B2, however, (Fig. 3) reductions are significantly lower and are of about 0-5% in total rainfall, while over most of Turkey significant rainfall increases are noticed. The predicted rainfall changes are similar to those observed over the EM during the recent decades (e.g., Alpert, 2004, Fig. 1.6.1; IPCC,2001) that also show larger decreases over the NE Mediterranean and some small increases over the SE Mediterranean.

EXTREME TEMPERATURES

In order to estimate the projections for extremes it is necessary to perform either a dynamical downscaling or a statistical interpretation. Here, we employ the method proposed by Deque (2006). The area on which we focus here is over N. Israel and particularly the Jordan River upper Catchment. Fig. 4 shows the geographic area super composed with the model grid of 50 km interval.

In the JR area we focus on two stations one mountainous- Har Knaan- about 1000 m high and the other a nearby Valley station Kfar Blum at about -200 m elevation. Both stations with about 1200 m height separation fall within one grid box of the RCM model. Next, let us illustrate how the statistical downscaling is performed for these two stations. Figure 5a shows the centile daily maximum temperature, Tmax, distribution in the mountain station for 1961-1990 observations and the control run. In addition, the same distributions for the two scenarios A2 & B2 are shown. As expected the scenarios are significantly warmer for all centiles. However, the control run has also a warm bias. As suggested by Deque et al (2006), this bias is removed for each centile and the same bias correction employed to correct the A2 & B2 scenarios (Fig. 5b). Figure 5c shows the final result for the Valley stations- Kfar Blum in the UCJR. The most extreme daily Tmax observed in this station for 1961-1990, was of about 42°C while in scenario A2 the expected total daily maximum is expected to be of about 48°C; a temperature rise of about 6°C. A similar increase is projected for most of the centiles. In scenario B2 the temperature increases are lower of the order of about 4°C. Figure 6 shows the regular Tmax distributions for all four curves for the mountain station. Interesting to note is that the most common Tmax value in the 1961-1990 observations is about 29°C and changes to 32.5 and 34°C for B2 & A2 scenarios, respectively. It is interesting to note that secondary peaks exist for circled values of the temperature and this seems to be the result of the tendency of meteorologists to circle the measured value of the temperature. Obviously, the bias-correction methodology transfers these secondary peaks further into the other curves.

EXTREME RAINFALL

Figures 7a, b show the centile distributions of the rainfall in the mountain station performed analogously to that for the temperature in Figs 5a, b. Here, the daily rainfall is predicted to be lower in the 2071-2100 scenarios for nearly all the centiles. However, in the few upper centiles (from about 95% and up) the tendency is just the opposite (Figs. 8a,b). In Fig. 8b the upper half-centile (99.5-100%) is zoomed in and clearly shows significant increases in the heavy rainfall daily intensities. Similar statistical interpretation (or statistical downscaling) for twelve stations all over Israel are summarized in Table 1. The table shows the number of extreme rainfall days exceeding 50 mm/d for a period of 30 y. There are a few interesting results to point out. First, stations close to each other but with significant differences like Har Knaan and Kfar Blum (numbers 10 & 11) in the JR basin or Jerusalem & Kiryat Anavim (numbers 3 & 4) show also significant variations in the future scenarios.

Second, the more northerly mountainous stations (7, 8, 10 &12) have generally larger frequencies of heavy rainfall. However there are exceptions like Kiryat Anavim (number 4).

Another interesting result is the change of the seasonal distribution of the heavy rainfall days (Figure 9). Figure 9 shows that there is a tendency in the global warming scenario B2 to obtain more heavy rainfall days in autumn and early winter. For instance, 6 days in Oct compared to zero in current climate or 16 compared to 7 for Dec. At the same time a reduction in Jan from 10 days to only 4. These are all number of days in a period of 30 years. In A2, however, the tendency for heavy rain days is in the spring.

Figures 10a, b summarizes the annual averages as well as standard deviations for all 12 stations in Israel for which the statistical downscaling procedure was applied. The major finding is decreases in annual rainfall associated with increases in the standards deviations. These fit many other studies that predict increases in the variability, e.g IPCC (2001). In the Mediterranean this goes paradoxically with decrease of rainfall as discussed by Alpert et al (2002), Alpert (2004).

SYNOPTIC SYSTEMS

The significant projected temperature and rainfall variations described earlier may probably be associated with some changes in the distributions of the weather as expressed by the different synoptic systems that dominate the EM area. Hence, it is interesting to know whether the global models are able to “see” the observed recent synoptic trends. Figure 11 shows the annual frequencies (expressed in days per year) of the major seven synoptic systems in the EM. The systems were objectively analyzed for 1950-2000 from NNRP reanalysis as described by Alpert et al (2004). In Fig. 11 the observed and the ECHAM4/OPYC3 frequencies are compared. It is interesting to note the global ECHAM model is very capable in reproducing the frequencies of the different system with outstanding accuracy. These are the good news. However, the most significant increasing trend in the frequency of the Red-Sea Trough (RST) is not simulated. Figure 13 shows that this increasing trend in the RST system is not captured also by the HadCM3 global model. Also shown is the frequency variation of the RST in ECHAM B2 scenario going to 2099. The global trend is decreasing through the full period of simulation 1950-2099 even though a strong increasing trend was observed in the NNRP reanalysis for 1948-2003. This possibly means that the RST trend was not associated with the GHG global warming, but by some natural climate oscillation not accounted for in AOGCMs.. This suggests that further investigation is required in order to better understand the potential impact of these findings on the confidence we can have in the global modeling results for the EM.

SUMMARY

Large-scale predictions over the Mediterranean suggest: up to 35% rainfall reductions and 3-5 Deg warming by 2071-2100. Our RCM findings support these and suggest further decrease in rainfall, increase in temperatures and a tendency to a more extreme climate. Much more detail can be derived from the RCM particularly with statistical downscaling as performed here over Israel with focus on a crucial small area the Upper Catchment of the Jordan River, N. Israel.

While most of the Mediterranean shows rainfall decreasing trends, there are rainfall increases over south/central Israel. These maybe associated with the significant observed increases in the frequencies of the Red-Sea Trough synoptic system. This finding, however, is not noticed by the global models.

Another problem is that the maximum heating observed (since 1948) is found over the Mediterranean Sea, but is predicted for the 21st century to be over land!

RCM simulations suggest a significant factor of increase in the number of the heavy rain days (above 50 mm/d) over Israel - the Jordan River Basin. Averaged over the six stations in the north (except station Eilon all in the JR Basin) there is an average increase of 13.7 days and 2.7 days for the B2 and A2 respectively. Percentagewise these corresponds to +46% and +9% for A2 and B2 respectively.

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Table 1. Extreme rainfall days (> 50 mm/d) (30 y periods)
In paranthesis the percentegewise increase (as compared to the control run)

No.	station	0bservation 1961-1990	Control 1961-1990	B2 2071-2100	A2 2071-2100
1	**Beer Sheva**	1	1	2 (+100)	1 (0)
2	**Dorot**	13	6	2 (-67)	2 (-67)
3	**Jerusalem**	43	44	24 (-45)	30 (-32)
4	**Kiriat Anavim**	73	65	67 (+3)	53 (-18)
5	**Tel Aviv**	28	22	24 (+9)	23 (+5)
6	**Kiriat Shaul**	30	32	27 (-16)	24 (-25)
7	**Eilon**	56	44	67 (+52)	46 (+5)
8	**Yiron**	59	46	65 (+41)	48 (+4)
9	**Kinneret**	8	4	2 (-50)	10 (+150)
10	**Har Knaan**	37	36	50 (+39)	38 (+6)
11	**Kfar Blum**	12	6	19 (+217)	14 (+133)
12	**Kfar Giladi**	53	44	59 (+34)	40 (-9)
	Average total	34.4	29.2	34.0 (+16)	27.4 (-6)
	Average North	37.5	30.0	43.7 (+46)	32.7 (+9)

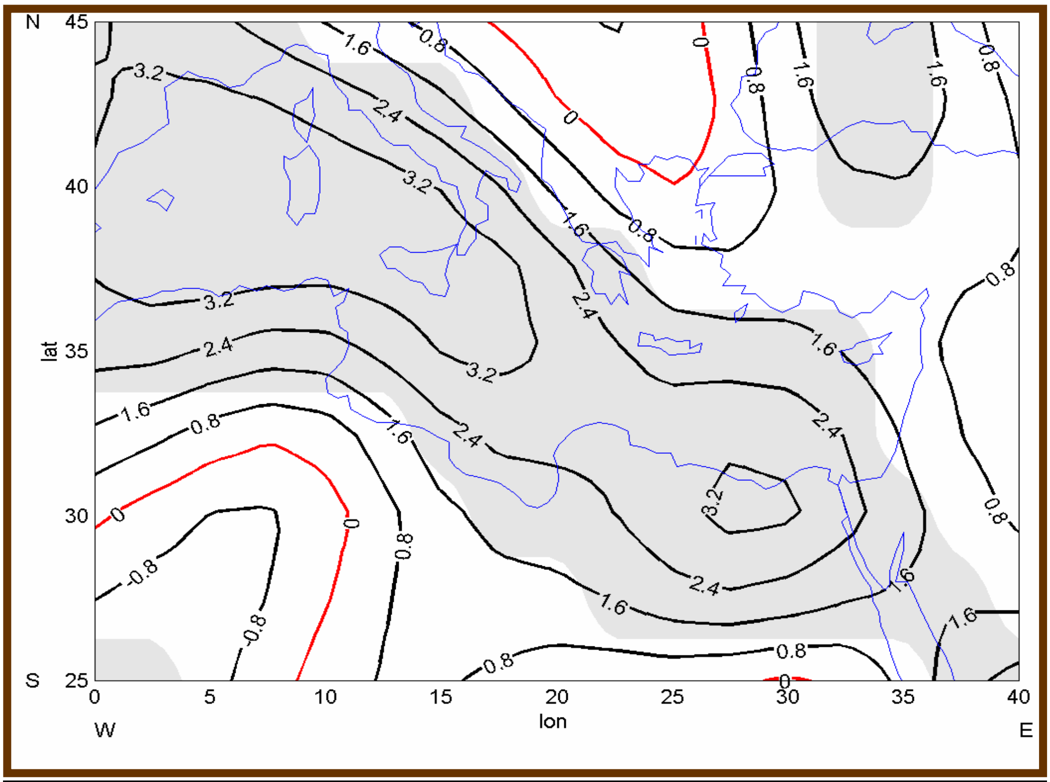


Figure 1. Trend summer (JJA) 850 hPa temperature (°C/100y)- NNRP reanalysis (From Saaroni et al, 2003)

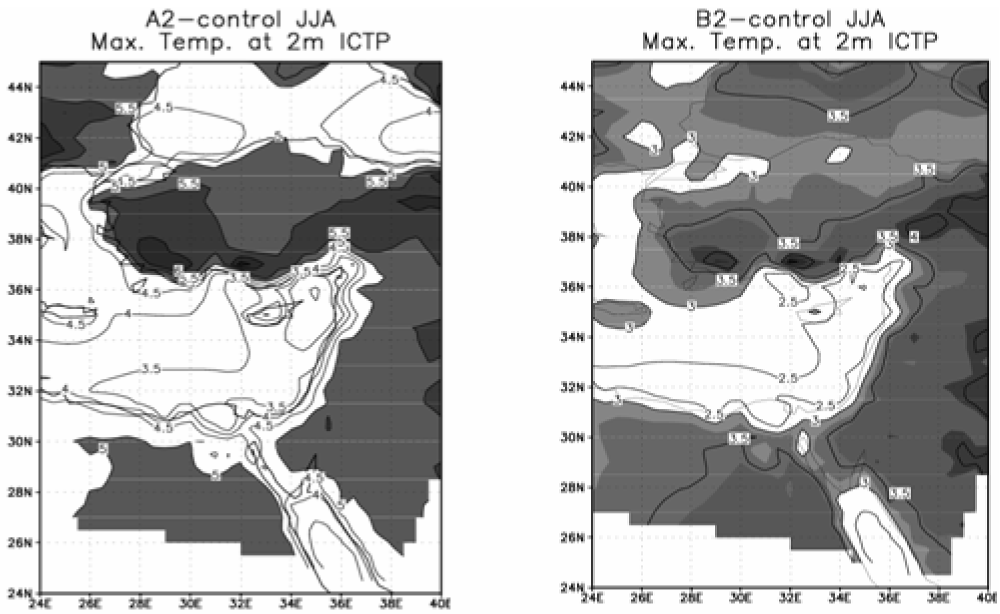


Figure 2.

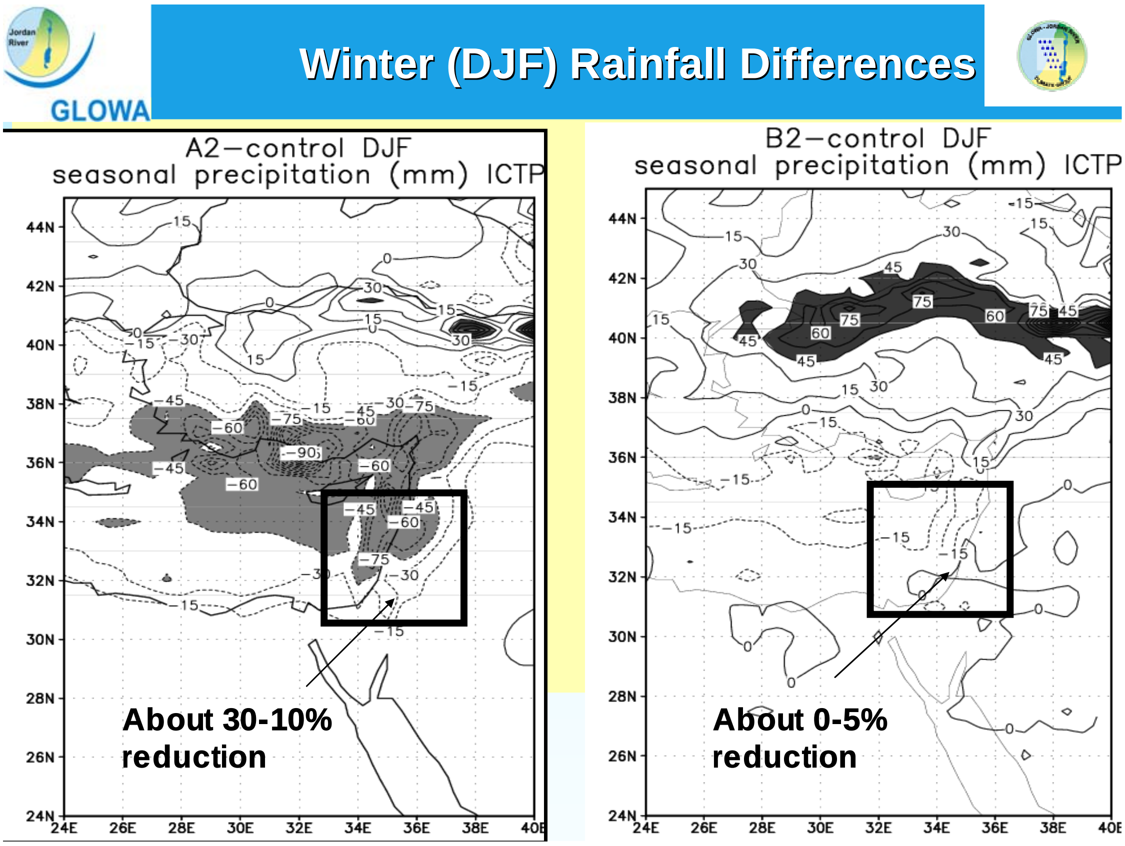


Figure 3. The predicted change in the main winter (DJF) rainfall based on RCM ICTP run for A2 and B2 scenarios, respectively.. The black box is centered over Israel and the Jordan-River basin.

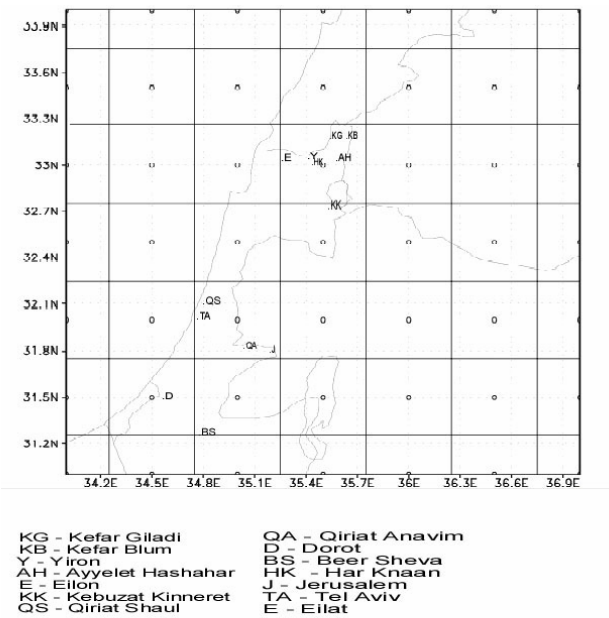
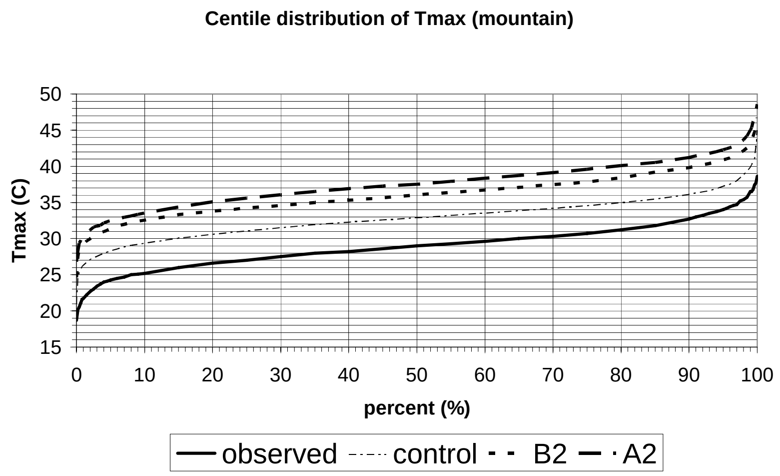


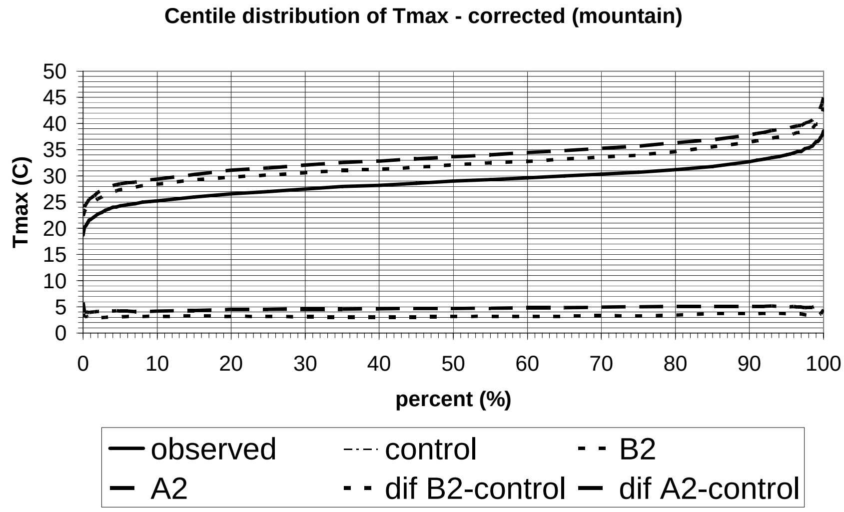
Figure 4

a



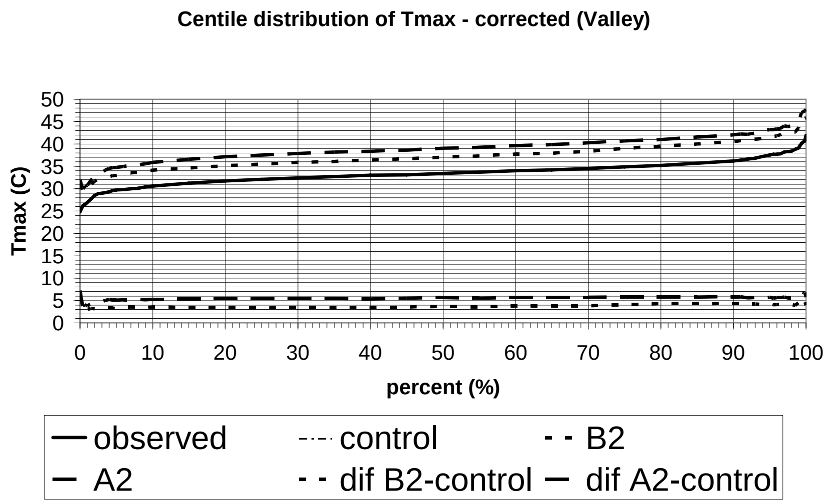
Centile distribution of Tmax (mountain)
Tmax (C)
percent (%)
observed
control
B2
A2

b



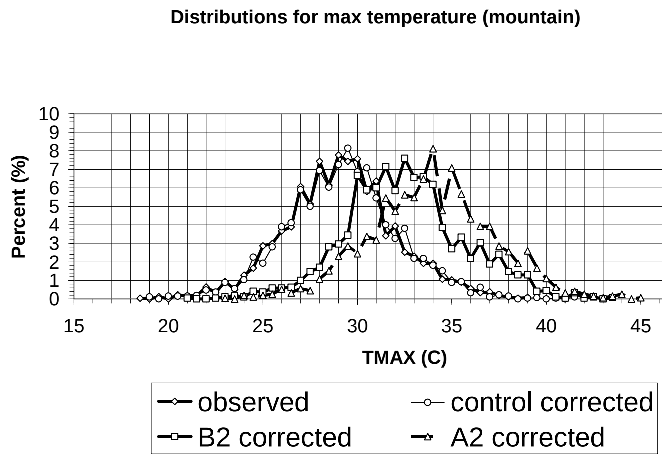
Centile distribution of Tmax - corrected (mountain)
Tmax (C)
percent (%)
observed
control
B2
A2
dif B2-control
dif A2-control

c



Centile distribution of Tmax - corrected (Valley)
Tmax (C)
percent (%)
observed
control
B2
A2
dif B2-control
dif A2-control

Figure 5



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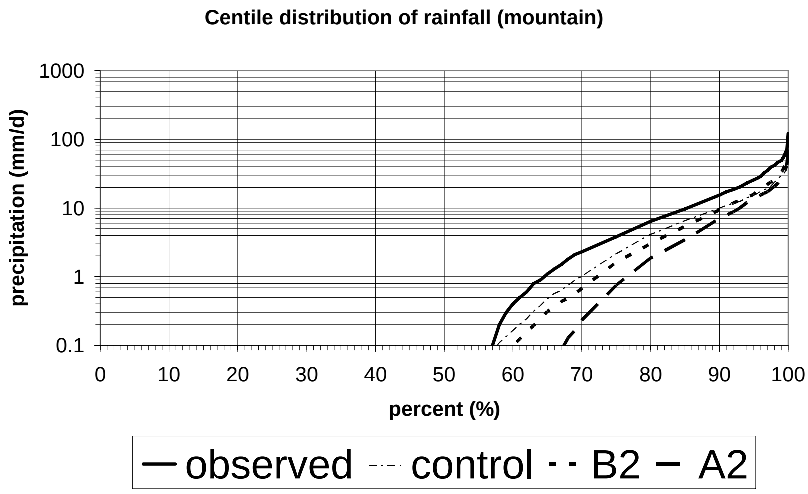

Figure 7a:

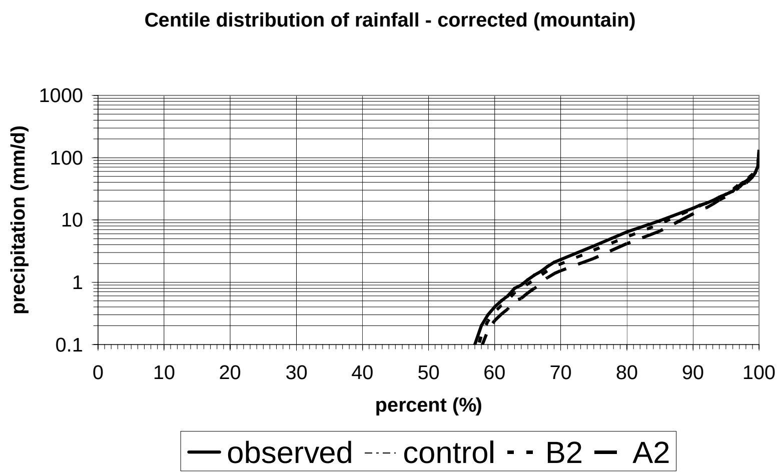

Figure 7b:

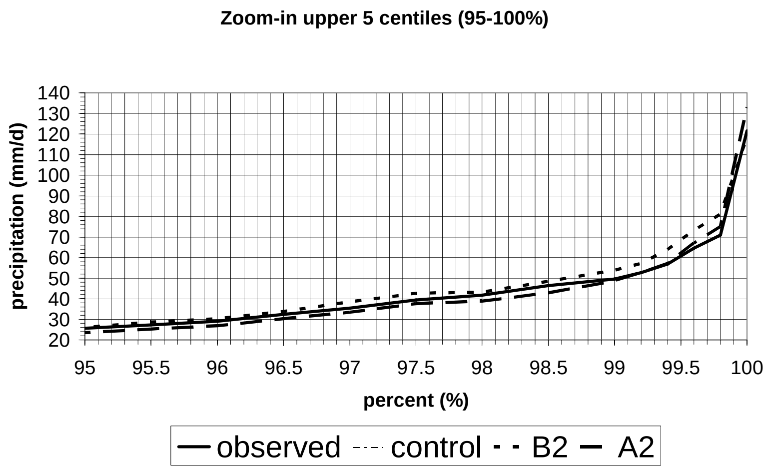

Figure 8a:

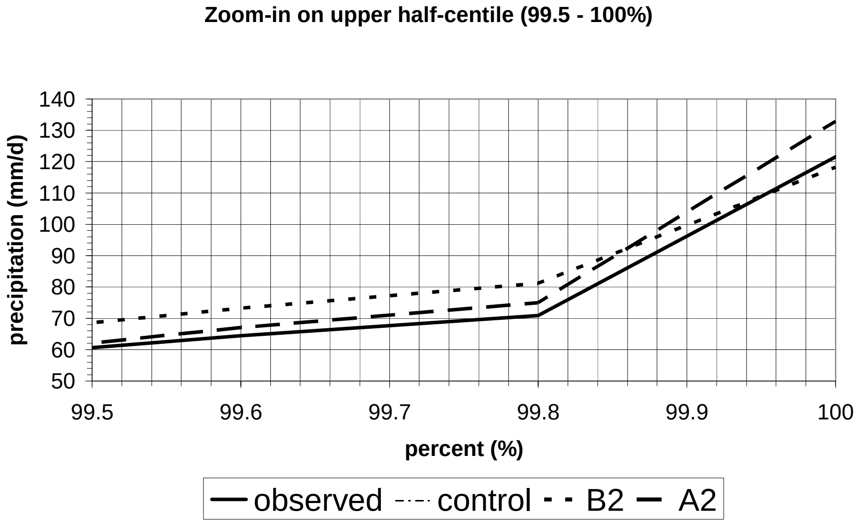

Figure 8b:

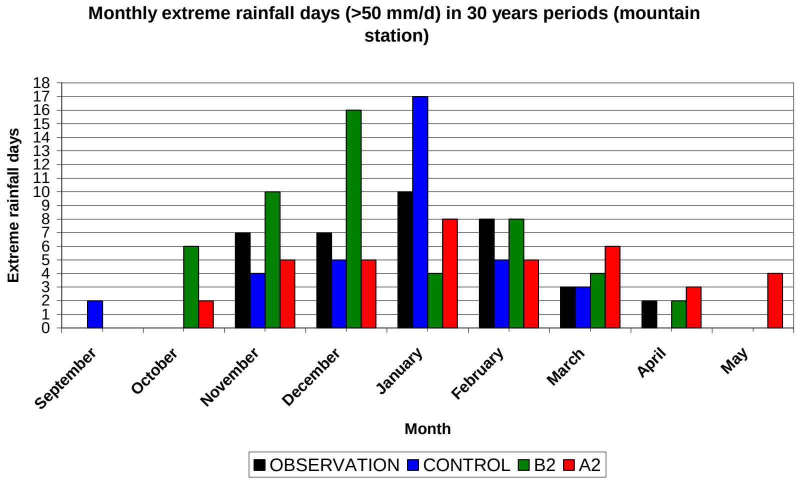

Figure 9

a

b

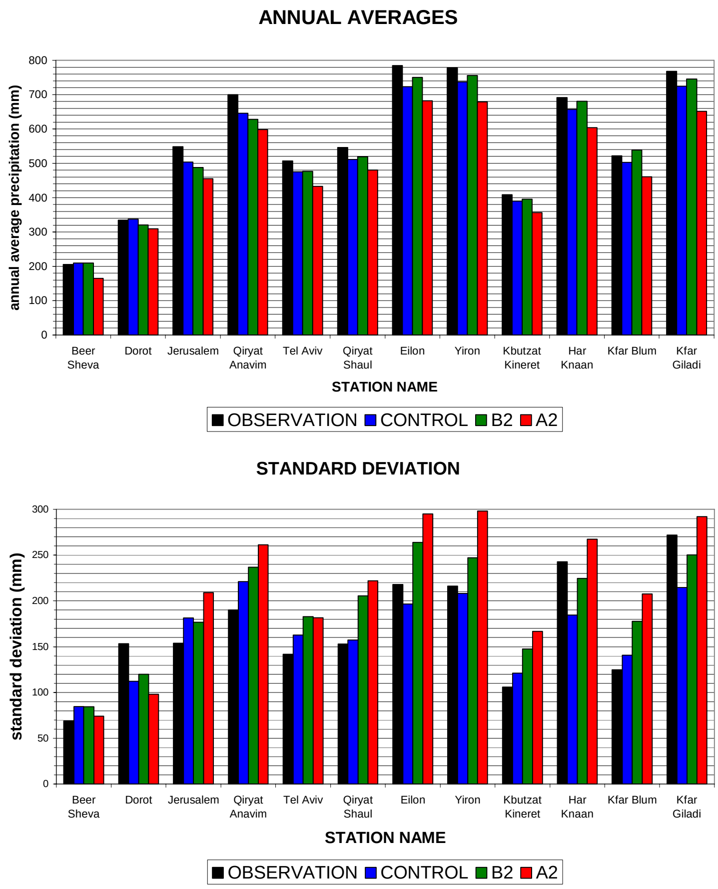

Figure 10

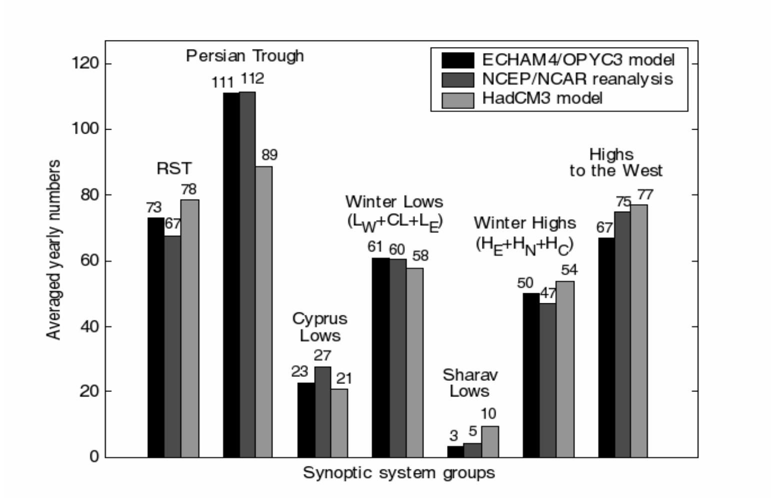

Figure 11:

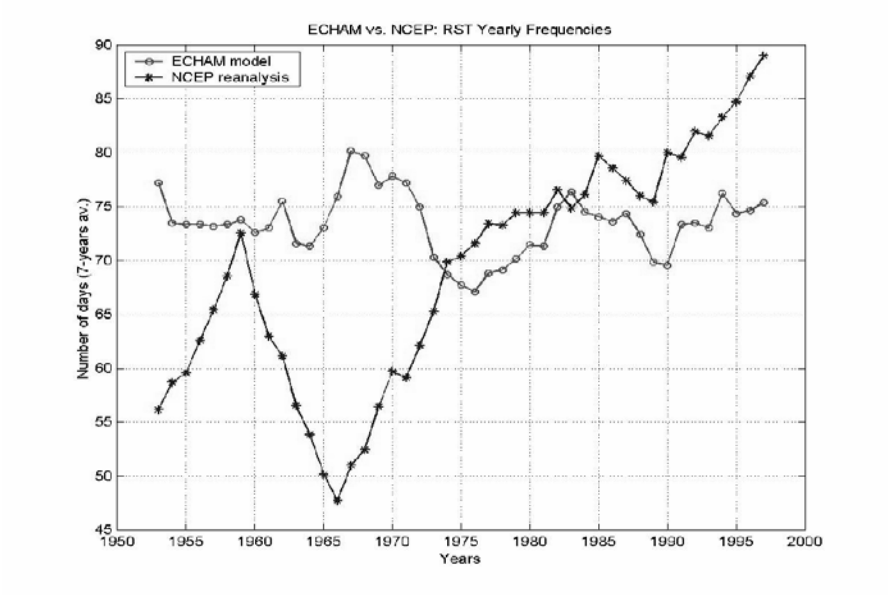

Figure 12:

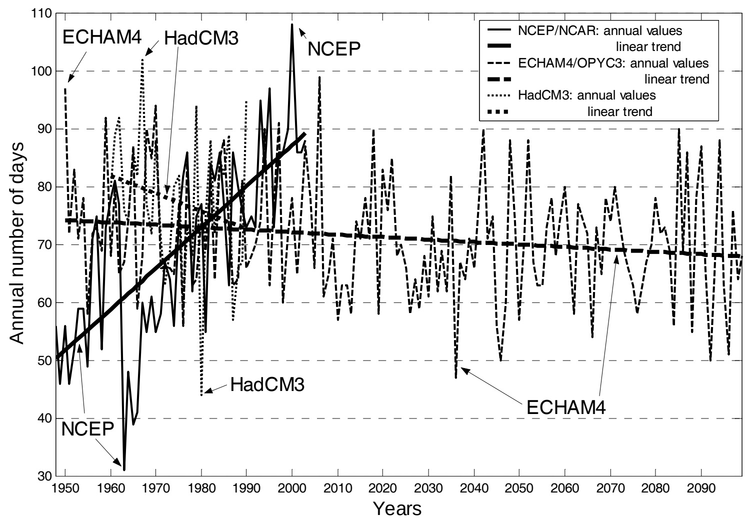

Figure 13:

THE CLIMATE CHANGE AND WATER RESOURCES PROJECTS OF SOUTHERN TURKEY

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ABSTRACT

The climate of a region on earth is the average weather which is experienced over a period of time. Rainfall, sunshine, wind, humidity, and temperature are basic factors that determine the climate at a location. The weather changes suddenly and man can easily notice it, but the climate changes take a long time to settle in and are therefore less obvious by man. Over the last 150-200 years the change has been taking place too rapidly. Human activities are believed to be responsible for this change, and the scientist worry about it. In case of Middle East, everybody worries about the climate change, due to the water stress felt to a certain degree, by all the member states of the region.

Turkey is located between Europe and Asia and also very near to Middle East. The land surface area is 779 452 km^2 and the population of about 75 million. The Asian part; Anatolia is plateau rising progressively towards the east. Annual rainfall in Turkey varies between 220 mm to 2500 mm with an average of 642.6 mm and this corresponds to an average annual rainfall of 501 km^3. Approximately 186 km^3 of this water flows in rivers as surface water. The consumable water volume is 95.0 Km^3, and at present the actual consumed volume is 25.9 Km^3.

The water potential of the Mediterranean part of Turkey including the Aegean coastal zone is at a level of mean annual about 8.2 x 10^9 m^3. The size of irrigable land, in this part of the country is about 1.8x10^6 ha, and there is very high tourism potential in the region. The main water courses along the Mediterrenean coast of Turkey, from east to west, include the Ceyhan, Seyhan, Goksu, Koprucay, Manavgat, Aksu, and Esencay rivers. All together they have 35x10^9 m^3 annual outflow.

The most important water resources of the eastern and south eastern part of the Euphrates and Tigris rivers, together they constitute 28.5 % of all the water resources of country. They originate in eastern part of Anatolia. In the upstream of river basins of eastern Anatolia, the the spring floods produced by snow melt, constitute approximately 50-70 % of annual flow,and the winter precipitation occurs mostly in solid form. They cross the border to Syria and Iraq. Before the scarcity of water will be felt more and more strongly due to climatic change in the region, the author believes that, the road map to an everlasting mutual trust among the Middle Easterners will stand to the test of time, and Turkish proposal to reach an equitable and satisfactory means for allocating water of Euphrates and Tigris river system to the riparian sates; Turkey, Syria and Iraq, will reinforce this trust on its part.

In Middle East, besides the available technologies for desalinization and reuse of waste water, there was and still there is an alternative water supply source; in 1986, Turkey

proposed a fresh water, technically feasible, pipeline project to divert about 6 MCM /day from Seyhan and Ceyhan rivers, to the Arab countries in the Middle East. Both of Seyhan and Ceyhan rivers are national rivers and the amount of the water to be transported was the surplus at the time of the proposal. At that time the project cost has been estimated as US $ 20 billion, on condition that local work force, construction material available at each country would be used.

A concrete example of Turkish good will is Manavgat water supply project. Starting from 1992, Turkish State Hydraulics Work; DSI was authorized to develop a water supply project from the Manavgat river which has an average 147 m^3/sec runoff rate. Originally concept initiating the Manavgat water supply project was to answer the increased demand for fresh water of the Mediterranean coastal region during summer when the Tourist activities reach at its peak. In the mean time it would be a good change to meet the demands which may come from the neighboring countries. The project ready to operate with all the facilities has been decided to be privatized on 23.02.2004.

For decades southeastern part of Anatolian peninsula is believed to be the least economically developed region of Turkey. Turkey started South Eastern Anatolian Project (GAP) in 60's with the intention to harness the hydropower potential of the Euphrates and Tigris rivers. The Southeastern Anatolian Project is said to be one of the biggest irrigated water resources utilizations projects and it covers an area of 74 000 km2, including the plains lying between the rivers of Euphrates and Tigris, and having a population of 5.5 million which is about 8 % of the national total. GAP is a group of thirteen projects and their subprojects which are multi-purpose; irrigation, hydropower, domestic water supply and flood control. Upon the full development of the project, besides the irrigation of 1.7 million ha of land, Turkey plans to produce of 27.3 TWh energy. If the demand arises and required by Middle East countries, Southeastern Anatolia is hoped to be "a close and dependable wholesale market" of vegetables and other food products produced at GAP, at very affordable prices as the globalization has more and more affect on human life.

According to the view of the author, the signing of international agreements for water can not be the ultimate solution to the chronic water shortage of Middle Easterners. The local governments has to provide more funding for the training of farmers on more effective use of water like drip irrigation and subsidize research on modern agricultural techniques in water and land use. Also the experiments with crops to find the most suitable one to the climate conditions of the region will help to reduce water waste. Rather than to use water uneconomically as in wild flooding method in irrigation which is the common experience of centuries, and accept water as a substance granted by Allah's, one should believe that to get optimum food from the least amount of water to ensure sustainable development in the region.

Key Words: Climate Change, Middle East, Water Scarcity, Turkey, Euphrates and Tigris rivers' System, Peace Pipe Line Project, Manavgat Water Supply Project, South Eastern Anatolian Project (GAP), Modern Irrigation Techniques

INTRODUCTION TO CLIMATE CHANGE

The "Climate change" can be defined as the variation in the Earth's global climate or in regional climates over time. The change in the variability or average state of weather over decades or millions of years is described as the climate change. The reasons may originate from the processes related to Earth, or from external forces such as the variations in sunlight intensity, more recently, from human activities. The variations in solar radiation, the Earth's orbit, and greenhouse gas concentrations are often called climate forgings and they are the basic external factors which strongly affect the climate of earth. The rise in average surface temperature on earth, simply known as global warming is the most common understanding of the climate change.

However, there are also changes within the Earth's environment that can affect the climate change and they can be listed as [1]:

- As one of the most sensitive indicators of climate change; the retreating of Glaciers during climate warming on moderate time scales
- The change of ocean currents pattern and processes which are believed to play a key role in redistributing the heat on earth
- The climate change can be a self-perpetuating process, for example during a decade of dry period, the prevailing conditions may cause lakes to shrink, plains to dry up and deserts to expand. In turn, these conditions may lead to less rainfall in the following years. The recently observed changes of environmental cycles related to climate change.
- The greenhouse effect, defined as the warming produced as greenhouse gases which trap heat, and play a key role in regulating Earth's temperature.
- The rising carbon dioxide levels since 1950 are implicated as the primary cause to global warming.
- The collide of the North and South American plates to form the Isthmus of Panama and shut off direct mixing between the Atlantic and Pacific Ocean has been implicated in the intensification of the present ice age.
- Although the 11–year sunspot cycle does not manifest itself clearly in the available climate data, the 11–year solar cycle and longer-term modulations are considered to be influential in triggering the Little Ice Age and for some of the warming observed from 1900 to 1950.
- The repeated advance and retreat of the Sahara desert
- Huge eruptions, known as large igneous provinces, occur only a few times every hundred million years, but can reshape climate for millions of years and cause mass extinctions.
- Anthropogenic factors; such as the increase in CO2 levels due to emissions from fossil fuel combustion, followed by aerosols (particulate matter in the atmosphere) which exerts a cooling effect, land use, ozone depletion, and deforestation
- CO2 levels rise from a concentration of 370 ppm today is projected to reach more than 560 ppm before the end of the 21st century due to intensive use of fossil fuels
- The cooling influence due to anthropogenic aerosols, particularly sulphate aerosols from fossil fuel combustion
- The change the albedo of the earth surface by influencing the ground cover and altering the amount of sunlight which is absorbed.

All the changes listed above are being also observed in Middle East region of the earth to varying extend. Also the birth rate of the nations living in this region of the world is one of the highest in the world, and the agricultural practices used by most of the countries here is very traditional and need improvement both in land use and water use. Therefore the water stress is felt more and more. The region should seek for peaceful solutions rather than to pronounce the terms like “water wars”. Because the Middle East is one of the poorest areas of the world in water supply and this problem is increasing. For example, the need for drinking water is solved by refining seawater and ground water at a large cost. According to the 1992 data, 15.6×10^6 m^3 of salty water is refined per day [2].

TURKISH STAND ON THE WATER ISSUE

Turkey, in various meetings, declared that it would provide water when demanded to the all Middle Eastern countries that need water, Northern African countries and even to Greek islands. In Memorandum of Understanding of VII Term Meeting of Turkey – Saudi Arabia Mixed Economic Commission, Turkey stated that it is ready to supply water to Saudi Arabia from Manavgat River. Also in the declaration performed by Turkish officials, some demands for Manavgat water besides Israel was stated and it was said that Algeria and Morocco were interested in the issue. The project ready to operate with all the facilities, has been decided to be privatized on 23.02.2004. It is hoped that, the exporting and related processes will be simpler and quicker.

Turkey is a country located between Europe and Asia, next to the Middle East Region, and has a population of about 75 million and surface area of 779 452 km^2 including the lakes (Fig. 1). Turkey has the continental climate at the interior part and the Mediterranean climate at the Aegean and Mediterranean regions. There are seven geographical regions in Turkey. The mean annual precipitation is 642.5 mm, ranging from 250 mm at central Anatolia to 2500 mm at Eastern Black Sea region (Figure 2), and The average value of the total water volume is about 501.0 Km^3 .The figures for the surface water potential of Turkey can be stated 186.05 Km^3 as surface runoff with a runoff coefficient of 37 %, 95.0 Km^3 as consumable water volume, 25.9 Km^3 as the actual consumed volume, and 12.0 Km^3 as exploitable ground water potential. It is important to note that 100 % use of this potential is hardly possible. Considering the present population of Turkey, the existing water potential corresponds to an annual per capita water supply of 1460 m^3 that means an extended drought may create very serious problems, this point needs more attention especially in a period during which the change in the trend of the climate in the region is pronounced very strongly.

Figure 1. Topographical map and main cities in Turkey

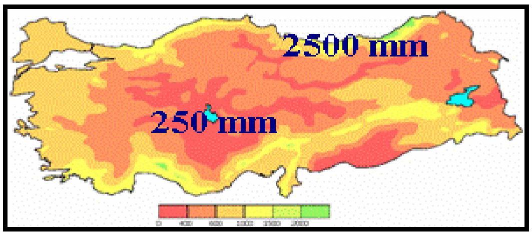

Figure 2. Annual precipitation in Turkey [3]

There are 26 water basins in the country, and the water and land resources of each basin are given in Table 1 [4]. The water potential of the Mediterranean part of Turkey including the Aegean coastal zone is at a level of mean annual about 8.2 x 10^9 m^3. The size of irrigable land, in this part of the country is about $1.8x10^6$ ha, and there is very high tourism potential in the region. The main water courses along the

Mediterrenean coast of Turkey, from east to west, include the Ceyhan, Seyhan, Goksu, Koprucay, Manavgat, Aksu, and Esencay rivers (Figure 3). All together they have $35x10^9$ m^3 annual outflow.

There may be other good quality water source along Mediterranean coastal strip, besides Manavgat water supply system. Actually if all the rivers flowing into Mediterranean Sea from Syrian border to Muğla, Köycegiz are taken into account, they constitute of about another 20 % of the total water potential of Turkey (Table 1) [5].

Table 1. Water and soil resources of Turkey [4].

Basin			*Water Potentials of Basin*			Impounded Water Within The Basin		Soil Resources Of Basin	
No	**Name**	**Area (km^2)**	**Annual Precipitation (mm)**	**Flow (km^3)**	Discharge ($lt/s/km^2$)	Number Of Dams	**Impounded Water (hm^3)**	**Land Area (ha)**	**Irrigable Land Area (ha)**
1	Meric Ergene	14560	604	1.33	2.9	21	1817	1095320	1077992
2	Marmara	24100	728.7	8.33	11	58	2894.5	865704	729957
3	Susurluk	22399	711.6	5.43	7.2	26	3848	850046	755934
4	North Aegean Basin	10003	624.2	2.09	7.4	15	797	367479	316348
5	Gediz	18000	603	1.95	3.6	16	3565.9	667207	623403
6	K. Menderes	6907	727.4	1.19	5.3	17	1697.7	223437	194799
7	B. Menderes	24976	664.3	3.03	3.9	22	2739.9	104296	907383
8	West Mediterranean	20953	875.8	8.93	12.4	25	1830	437356	406601
9	Antalya	19577	1000.4	11.06	24.2	14	2858	451224	448111
10	Burdur Lakes	6374	446.3	0.5	1.8	9	161.7	251403	249484
11	Akarcay	7605	451.8	0.49	1.9	3	172	364411	359938
12	Sakarya	58160	524.7	6.4	3.6	45	6827.9	2814341	2681137
13	Western Black Sea	29598	811	9.93	10.6	28	2784	855008	640557
14	Yesilırmak	36114	496.5	5.8	5.1	44	6287.9	1617206	1401213
15	Kızılırmak	78180	446.1	6.48	2.6	78	23774.3	4049796	3761142
16	Konya Closed Basin	53850	416.8	4.52	2.5	25	2800.8	2182762	2134915
17	East Mediterranean	22048	745	11.07	15.6	11	10173.5	438281	327790
18	Seyhan	20450	624	8.01	12.3	18	6124.5	764673	714014
19	Asi (Orontes)	7796	815.6	1.17	3.4	8	11086.5	376240	331719
20	Ceyhan	21982	731.6	7.18	10.7	27	8229.3	779792	713670
21	Euphrates	127304	540.1	31.61	8.3	89	112193.2	4293793	4111316
22	Eastern Black Sea	24077	1198.2	14.9	19.5	41	1491.6	712575	350717
23	Coruh	19872	629.4	6.3	10.1	21	7467.3	326220	303362
24	Aras	27548	432.4	4.63	5.3	20	4085.2	642017	641137
25	Van Lake Closed B.	19405	474.3	2.39	5	7	608.7	436485	433319
26	Tigris	57614	807.2	21.33	13.1	42	30630.5	1148238	1137628
	Total	779452 (1)	642.6 (2)	86.05	209.3	730	246853.9	28054310	25753586

(1) Drainage area outside Turkey is not included. (2) Long term mean value

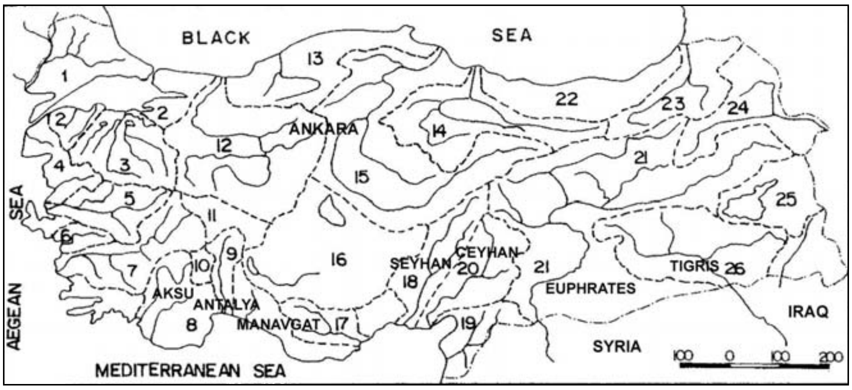

Figure 3. The Water Drainage Basins in Turkey and at Mediterranean Coastal Strip.

In connection with the water need of the Middle East region, it may be worth to mention that, the main river courses supplying most of the fresh water to the Middle Eastern countries are the river Nile, the river Jordan and the Euphrates and the Tigris (Figure 4) [6]. The Euphrates and the Tigris rivers are the most important water resources of at the eastern and southeastern Anatolia and constitute of 28.5 % of all the water potential of Turkey. The population projections, and the renewable water resources and water demand per capita of Middle East countries are given in Table 2 and Table 3 respectively. The rate of increase of the population is very much same in all the countries in the Middle East. The renewable water potentials of the countries of the region vary considerably, Iraq, Turkey and Syria have comparatively higher and the Palestine, Jordan, Israel and Saudi Arabia have much lower amounts of water per capita in the region as shown in Table 3.

Figure 4. Euphrates and Tigris river system.

The author believes that, with such a high birth rate, and renewable water potentials and estimated quantity of water per capita, any country in Middle East will face water shortage problems, and water scarcity during the period of droughts will be unbearable. It may be right time to look for reasonable and dependable solutions of the problem. Solutions at country level will not be realistic. Regional solutions will help. Both water and land use methods of present practice should be modernized. The rather high birth rate in the region may be another point to think about it.

Table 2. Population projections of the Middle East countries [7,8]

	Turkey	Irak	Jordan	Syria	İsrail	Palestine	Saudi Arabia
Years	Population (Thousand)						
1950	21 484	5 340	472	3 495	1 258	1 269 *	3 201
1980	46 316	14 093	2 225	8 978	3 764		9 604
1990	57 300	18 515	3 254	12 843	4 514	2 265 *	16 379
2000	68 234	25 075	4 972	16 813	6 084		21 484
2005	73 193	28 807	5 703	19 043	6 725		24 573
2010	78 081	32 534	6 338	21 432	7 315		27 664
2020	86 774	40 522	7 556	26 029	8 296	6 183 *	34 024
2035	96 573	52 833	9 149	31 724	9 545		42 865
2050	101 208	63 693	10 225	35 935	10 40 3		49 464

The Tigris and the Euphrates rises in the high mountains of northeastern Anatolia and flows down through Turkey, Syria and Iraq and join to form Shatt Al-Arab about 200 Km before they reach the Gulf (Figure 4) [6]. The surface runoff contributions of the riparian states to Euphrates and Tigris river system is given in Table 4.

Table 3. Renewable water resources and water amount per capita estimates in Middle East countries [9, 10, 11]

Year	Renewable water potential billion m^3	Estimated Amount of water in m^3/capita						
		1950	1990	2000	2005	2010	2020	2050
Turkey	110**	5120	1920	1612	1502	1408	1267	1086
Irak	109*	20411	5887	4346	3783	3350	2689	1711
Jordan	1,3*	2754	399	261	227	205	172	127
Syria	25*	7153	1946	1486	1312	1166	960	695
İsrail	2,2*	1748	487	361	327	300	265	211
Palestine	0,7***	552	309	-	-	-	113	-
S. Araba	4,55*	1421	278	211	185	164	133	92

Table 4. The runoff contribution of riparian states to the Euphrates and the Tigris rivers[6].

State	Euphrates	Tigris
Turkey	89 %	52 %
Syria	11 %	0 %
Iraq	0 %	48 %
Total	100 %	100 %

.
It seems that the anticipated combined demand for water from transboundary rivers by riparian counties is actually greater than the total volume of the river system as could be seen from Table 5, and at the moment the demands of the riparian states do not look like very realistic.

Table 5. The claims by the riparian states as the percentage of annual flow [6] .

State	On Euphrates	On Tigris
Turkey	52 %	14.1 %
Syria	32 %	5.4 %
Iraq	65 %	92.5 %
Total	149 %	112 %

The anticipated climate change in Middle East may be one of the most important forcing reasons for the riparian states to come together and reach a acceptable solution for all of them. All three riparian countries when agreed on a common agreement they will get equitable and optimal use of the available waters of the region that means Euphrates and Tigris River system will help the solve a big part of the water problems of Turkey, Syria and Iraq. In order to reach an agreement on the water issue of Euphrates and Tigris river system, according to the perception of the author, it is very important to use the same scientific and engineering and social criteria adopted internationally, in assessing the water and soil resources and also the needs of all the riparian states.

PEACE PIPELINE PROJECT

Going back in time, in 1986, Turkey proposed a fresh water supply project which was technically feasible at that time of proposal. It was named as "Peace Pipeline Project" to divert about 6 MCM /day from Seyhan and Ceyhan national rivers, to the countries in the Middle East. The amount of the water planned to be transported to the region, was the surplus at the time of the proposal. The water transfer concept attracted both positive and negative reactions. In the year 2006, when the water stress due to climatic change in the region is felt more severely, especially the initial political responses since 1986, deserve to be revised, because the technical feasibility of the project had not raised as strong arguments as the political ones . At that time the project cost has been estimated as US $ 20 billion, on condition that local work force, construction material available at each country would be used.

The proposed two pipelines:
The Western Line was planned to extend 2650 Km along the cities of Hama, Humus, Damascus, Amman, Yanbo and Medine (Figure 5.), and to have a capacity of 3.5 MCM/day and to end up at Mecca, would supply fresh water to Jordan, Palestine and the western part of Saudi Arabia. The unit cost of water was computed as US $ 0.84 according to the 1986 construction costs of US $ 8 billion for this branch. The water would be diverted from Seyhan River.

The Eastern Line was planned to extend 3900 Km along the cities located on the western coast of Persian Gulf (Figure 5.), and to have a capacity of 2.5 MCM/day, would supply fresh water to Syria, Kuwait, Bahrain and Qatar. The unit cost of water was computed as US $ 1.07 with 1986 construction costs of US $12 billion for this line. The water would be diverted from Ceyhan River.

The rather high initial investment for the project, instead of two pipeline system extending 6550 Km, some experts proposed a shorter line ending up at Jordon, with an annual capacity of 2.19 BCM, which is 1.6 times the annual capacity of Jordan River [12], so the water need Jordan and Palestine could be answered.

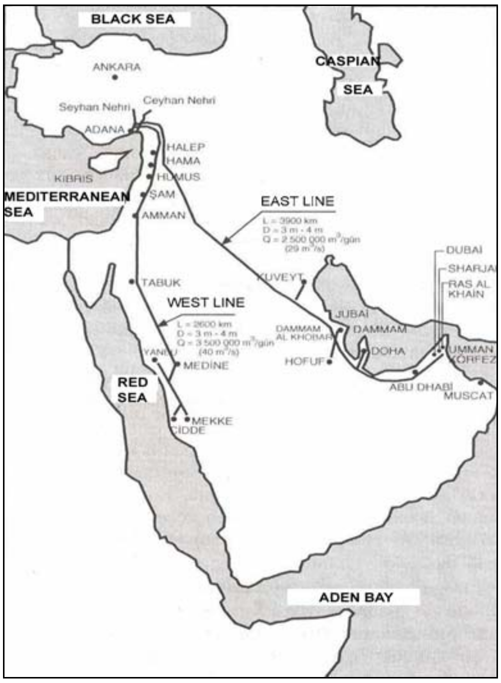

Figure 5. Peace Pipeline Project Concept to Middle East

In both cases, the initial investment should be provided by the countries that will benefit from the project. In the year 2005, at present political conjecture of Middle East, this will need a joint understanding which has to be based on mutual trust. If the chances are given, it is believed that the completion of the project will create an atmosphere of cooperation, stability and security in the region.

It might be important to mention about the possibility of using the desalinated water which is computed as US $ 0.68 [13] instead of "Peace Pipeline Project" water. The cost of desalinated water is not so cheap but it is around US $ 1.5 [12].

MANAVGAT WATER SUPPLY PROJECT

"Manavgat River Water Supply Project" is located near Manavgat town, Antalya province of Mediterranean Region (Figure 6). The project was started in 1992, it cost approximately 150 million $ and it was completed in 1999. With this project, 250 000 m³ refined and 250 000 m³ raw water, totaling 500000 m³ water will be transported down to the sea coast by means of pipelines and it will be loaded into tankers. The hydraulic flow chart and the cross section showing the basic components of the project is presented in Figure 7.

The original concept in initiating the Manavgat water supply project was to answer the increased demand for fresh water of the Mediterranean coastal region of Turkey, where during summer, when the Tourist activities reach at its peak. Also it was considered that this water would be a good possibility to meet the partial water need of some Middle Eastern countries and Northern Cyprus and Greek islands.

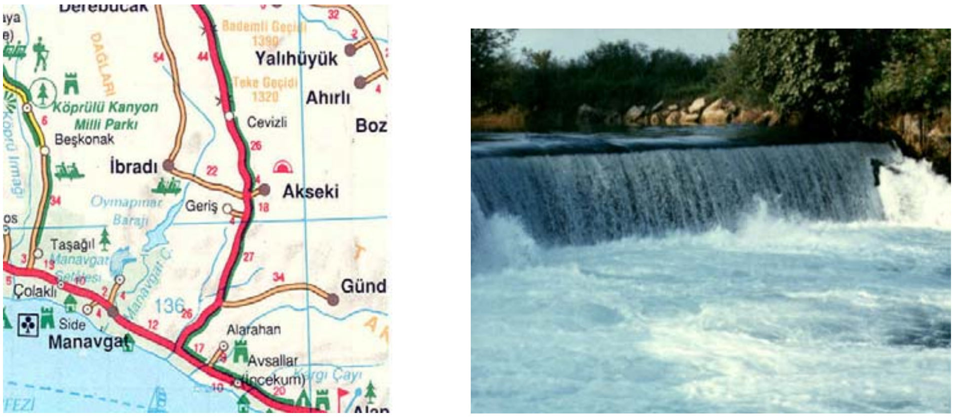

Figure 6. Manavgat river location map and Manavgat River.

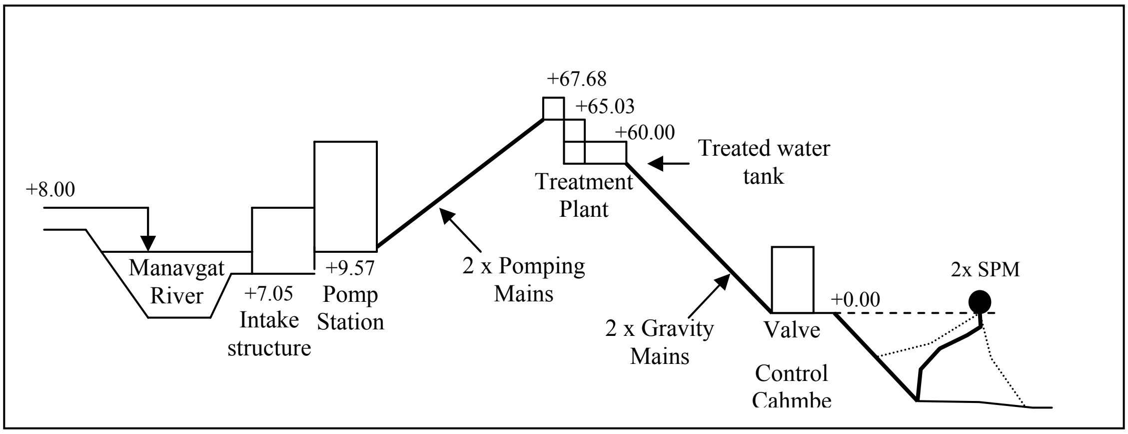

Figure 7. Hydraulic Flow Diagram of Manavgat Project

Till now, water has been being transported only to northern Cyprus. In 2004, Israel and Turkey agreed on water purchase of $50x10^6$ m³/year water from Turkey for 20 years, but in 2006 they agreed to freeze the agreement.

For example the transporting of water from Turkey to Greek Islands, Middle East and North African countries (Figure 8) can be done by one of the technologies of Water Pipeline, Water Tanker, or The Medusa Bay. The methodology to evaluate the alternatives, selected and approved by all partners will produce the best result from economic and financial points of view. In this connection it may be possible to get benefit of the experiences of other countries on the world. [14, 15].

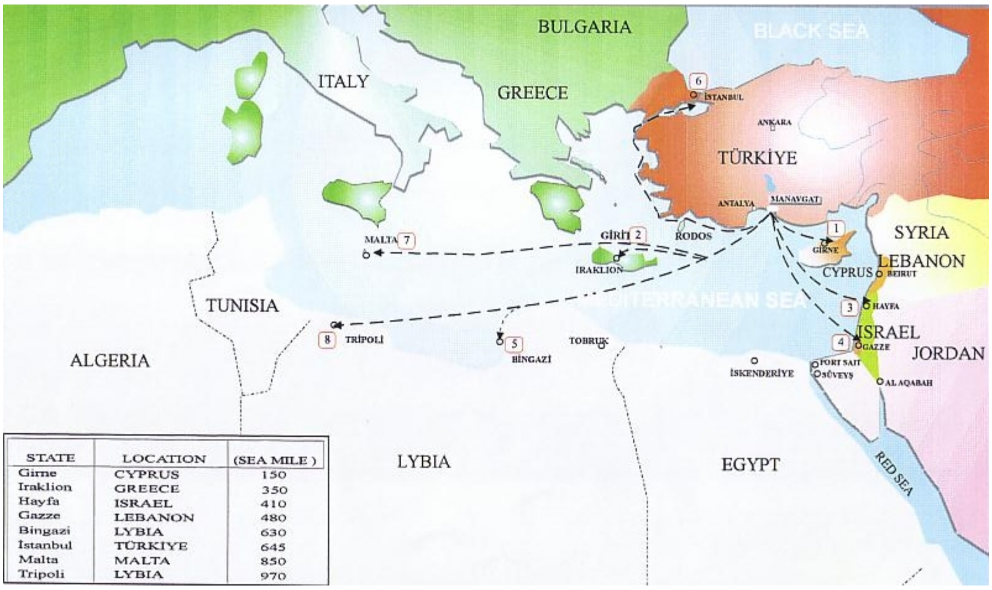

Figure 8. Alternative Countries For The Marketing of The Water from Manavgat River Water Supply Project [16].

GAP PROJECT

For decades southeastern part of Anatolian peninsula was the least economically developed region of Turkey. Turkey started GAP project in 60’s with the intention to harness the hydropower potential of the Euphrates and Tigris rivers. The Southeastern Anatolian Project is said to be one of the biggest irrigated water resources utilizations projects and it covers an area of 74 000 km2, including the plains lying between the rivers of Euphrates and Tigris, and having a population of 5 275 000 which is about 9 % of the national total (Figure 9). GAP is a group of thirteen projects and their subprojects which are multi-purpose; irrigation, hydropower, domestic water supply and flood control. Upon the full development of 22 dams and 19 hydropower plants, besides the irrigation of 1.69 million hectares of land, with an installed capacity of 75 % of the present capacity of the country, and this will double the total energy production of the country (22.3 TWh at present) [17].

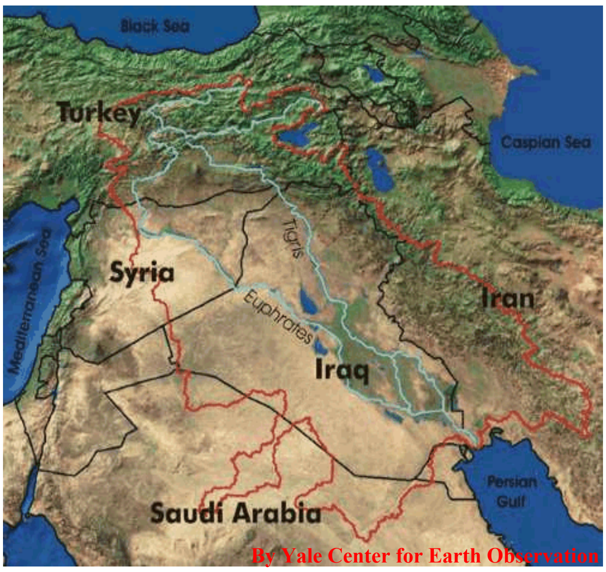

Figure 9. Location of GAP in Euprates and Tigris river system

CONCLUSIONS

In order to decrease the water stress and its negative impacts of the regional politics at Middle East, all possible partners should cooperate and bring together their good will and economic resources. The worsening climatic conditions may force them to reanalyze the past projects. A good some of initial investment from all national economic resources should also be allocated for the full development of the available land and water resources.

Parallel to technical evaluation of the existing conditions, it will be worth to mention the necessity of assessment of the political, administrative and environmental aspects of the projects of water exporting from Turkey to Middle East if there will be a demand for it.

It can be stated that, for the water scarcity problem of Middle East countries, "Manavgat River Water Supply Project" can be viewed as ready alternative to put in service, but it is a partial solution. Peace Pipe Line project may be another alternative but a long term project, and it must not be treated only to solve the big part of the water scarcity problem but also to cement a long lasting mutual trust needed for peaceful cohabitation in the region. If the demand arises and required by Middle East countries, Southeastern Anatolia is hoped to be "a close and dependable wholesale market" of vegetables and other food products produced at GAP, at very affordable prices as the globalization has more and more affect on human life.

According to the view of the author, the signing of international agreements for water can not be the ultimate solution to the chronic water shortage of Middle Easterners. The local governments has to provide more funding for the training of farmers on more effective use of water like drip irrigation and subsidize research on modern agricultural techniques in water and land use. Also the experiments with crops to find the most suitable one to the climate conditions of the region will help to reduce water waste. Rather than to use water uneconomically as in wild flooding method in irrigation which is the common experience of centuries, and accept water as a substance granted by Allah's, one should believe that to get optimum food from the least amount of water to ensure sustainable development in the region.

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