IMPACT OF GLOBAL WARMING ON THE EUPHRATES-TIGRIS WATERSHED

Jason P. Evans

Dept. Geology and Geophysics, Yale University, New Haven, CT 06520, USA, jason.evans@yale.edu

ABSTRACT
Over the last few decades demand for fresh water from the Euphrates-Tigris watershed has increased substantially, approaching (even exceeding in dry years) the total flow of the system. This situation leaves the area vulnerable to future changes in the water cycle. Here I present some analysis of GCM predictions for the region over the 21st century assuming emissions follow the IPCC scenario A2 ("business as usual"). Eighteen GCMs have submitted results for the A2 scenario to the Earth System Grid. The performance of the GCMs is assessed against observations collected from 2000 thru 2005. The ability to reproduce monthly precipitation and temperature over the Middle East varies considerably between models. The ensemble mean temperature increase over the 21st century is ~4ºC. The ensemble mean precipitation decreases by ~25mm, however precipitation predictions are characterized by an increase in inter-model variation rather than a coherent ensemble trend, such that although the ensemble trend is a decrease, several models predict an increase in precipitation.

Also presented are preliminary results of a regional climate modeling study investigating the impact of global warming on the Middle East. The region is modeled using MM5 run at 27km grid spacing and 23 levels in the vertical. Boundary conditions for the model are obtained from a CCSM3 (IPCC scenario A2) run simulating the 21st century. MM5 was run for three five year periods starting in 2000, 2048 and 2095. Results show the largest temperature increase occurring in Iran during summer, along with some cooling on the Eastern Black Sea coast. Results for precipitation indicate drying over Southern Turkey and the Eastern Mediterranean and wetting over much of the rest of the domain, particularly Iran. Ignoring man-made reservoirs, the regional model predicts a significant increase in the runoff produced in the Euphrates-Tigris watershed.

INTRODUCTION

Since a coordinated international attempt to mitigate global warming remains elusive, accurately predicting the impacts on a regional scale in order to assist adaptation efforts is increasingly important. This is especially true in poorer and politically unstable parts of the world where rapid, large scale adaptation may prove too costly and instead efforts need to be introduced gradually through time. To facilitate gradual adaptation, accurate predictions of the regional impacts of global warming as far into the future as possible are required.

This paper analyzes climate change in the Middle East during the 21st century as predicted by 18 Global Climate Models (GCMs). The simulations were run as part of the Intergovernmental Panel on Climate Change Fourth Assessment Report (IPCC AR4). They used the SRES A2 emission scenario which is the scenario closest to a "business as usual" scenario in the SRES family.

The Middle East (Figure 1) is largely arid to semi-arid and fresh water is often scarce and precious resource with major rivers such as the Khabur running dry in low precipitation years (e.g. 2000). The combination of a stressed fresh water resource, rapid population growth and pervasive political instability, substantially increases the vulnerability of the region to future climate change. Simulating the climate of the region is a challenge for climate models (Evans et al., 2004), due in part to the high natural inter-annual variability, the topography of the region which includes multiple mountain ranges and shorelines, and the presence of a slight cooling trend in recent decades despite the global trend being a warming. Mann, 2002) suggests that “natural variability has masked the influence of possible anthropogenic climate forcing in the past, but will not mask stronger projected trends in the future.”

This study seeks to quantify the projected 21st century climate change in the Middle East, including the uncertainty associated with this. First GCM performance is assessed against observational datasets of temperature and precipitation for the first five years of the 21st century. GCM projections for the middle and end of the 21st century are then analyzed.

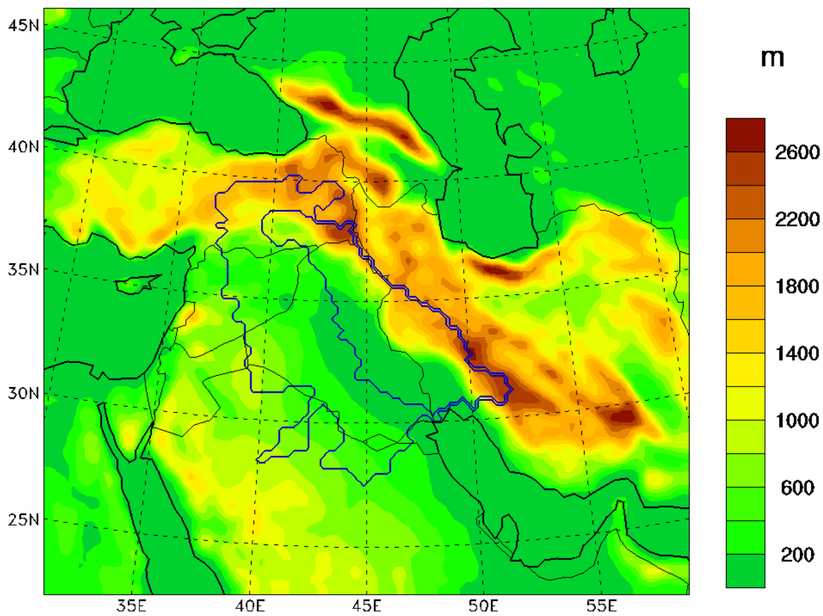

Figure 1. Regional climate model Middle East domain with Euphrates-Tigris watershed

MODELS AND DATA

This study uses output from coupled Ocean-Atmosphere GCMs for the IPCC AR4 archived at the Earth System Grid (http://www.earthsystemgrid.org/home/ home.htm). Eighteen GCMs provide output from a 21st century SRES A2 emission scenario simulation (see Table 1). Seven models provide up to five ensemble members for the SRES A2 scenario. Some models included the year 2000 in their 20th century model simulations (20C3M). In this case the 20C3M data (taken from the appropriate ensemble member) is used to bring the SRES A2 simulation data back to the beginning of the year 2000.

The regional climate model used was MM5-Noah. The PSU/NCAR (Pennsylvania State University / National Center for Atmospheric Research) mesoscale modeling system MM5 is described in Dudhia, 1993) and Grell et al., 1994). MM5 is a limited-area nonhydrostatic model that uses a terrain-following vertical coordinate system. It has 2-way nesting capabilities, and flexible physics options. In this study MM5 was implemented with the Reisner Mixed-Phase explicit moisture scheme (Reisner et al., 1998), the MRF planetary boundary layer scheme (Hong and Pan, 1996), the Rapid Radiative Transfer Model (RRTM) radiation scheme (Mlawer et al., 1997) and the Grell scheme for convective precipitation (Grell et al., 1994).

MM5 is operationally linked with the Noah Land Surface Model (LSM). Noah is a direct descendent of the Oregon State University (OSU) LSM (Mahrt and Ek, 1984: Mahrt and Pan, 1984: Pan and Mahrt, 1987), a sophisticated land surface model that has been extensively validated in both coupled and uncoupled studies (Chen and Mitchell, 1999: Chen and Dudhia, 2001). The Noah LSM simulates soil moisture, soil temperature, skin temperature, snowpack depth and water equivalent, canopy water content, and the energy flux and water flux terms of the surface energy balance and surface water balance. In its MM5-coupled form Noah has a diurnally dependent Penman potential evaporation (Mahrt and Ek, 1984), a four layer soil model (Mahrt and Pan, 1984), a primitive canopy model (Pan and Mahrt, 1987), modestly complex canopy resistance (Jacquemin and Noilhan, 1990), and a surface runoff scheme (Schaake et al., 1996).

MM5 has been applied successfully at grid cell resolutions ranging from greater than 100 km to less than 1 km and is used for both weather forecasts and climate research (Zaitchik et al., 2005: Evans et al., 2005). Here we apply the model at 27km horizontal resolution over a domain which includes much of the Middle East and the surrounding water bodies. **Error! Reference source not found.** shows the model domain excluding the rows and columns which are directly influenced by the boundary conditions. Three 5-year simulations were performed beginning at the start of the years 2000, 2048 and 2095. Initial and boundary conditions were obtained from the CCSM run5 simulation. The model was run with 23 vertical levels which were spaced more tightly near the ground surface.

Three global observational datasets were used to assess the GCMs performance at the beginning of the 21st century. The HadCRUT2v dataset (Jones and Moberg, 2003: Rayner et al., 2003) is a 5˚x5˚ surface temperature dataset created and maintained at the Climate Research Unit in the UK. The CMAP (Xie & Arkin, 1997) dataset is a 2.5˚x2.5˚ precipitation dataset created and maintained at the Climate Prediction Center in the USA. The GPCP dataset (Adler et al., 2003) is a 2.5˚x2.5˚ precipitation dataset created and maintained at the NASA/Goddard Space Flight Center's Laboratory for Atmospheres in the USA.

RESULTS

The GCM simulations were first compared to observational datasets for 2000-2005. Various statistics were calculated both globally and within the Middle East domain. The results show that while there is a significant range in Middle East Surface temperatures the PCM model has a ~2K negative bias compared to the nearest other GCMs (Figure 2). Results for precipitation are similar in this regard however this time it is the BCC model that is an outlier due to its low bias (Figure 3).

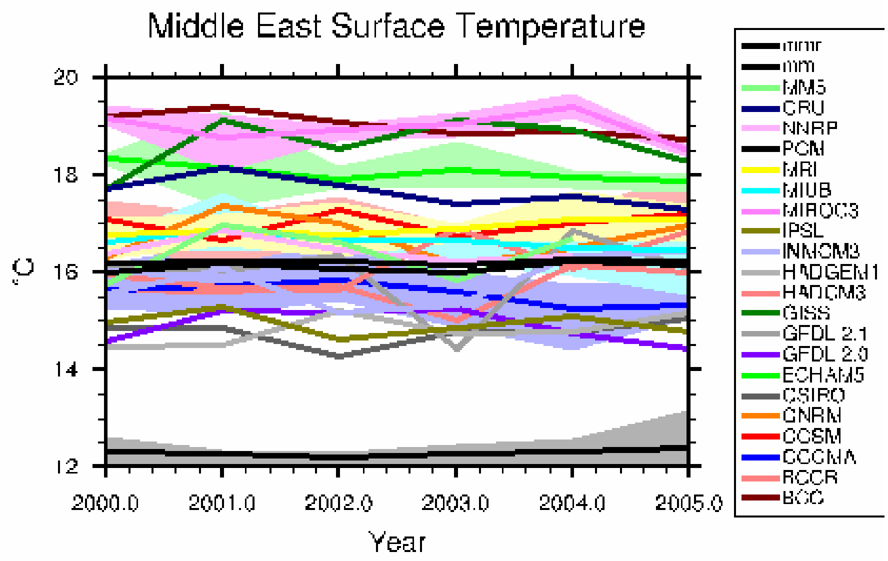

Figure 2. Middle East mean annual temperature. The ensemble envelope is shown in halftone color.

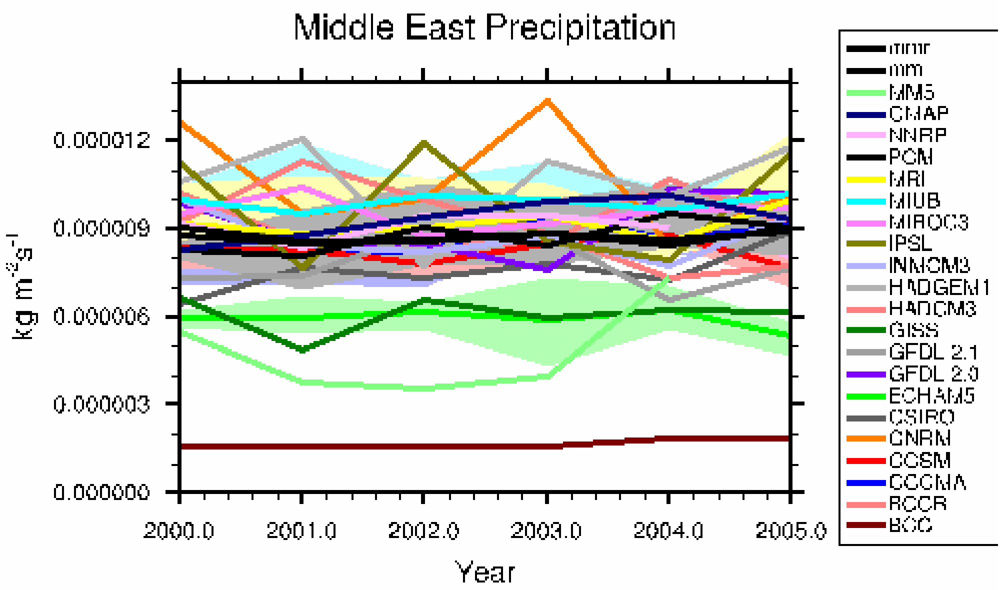

Figure 3. Middle East mean annual precipitation rate. The ensemble envelope is shown in halftone color.

Table 1. GCM models with simulation details

Model	*Institute (country)*	*Output Periods (Ensemble members used)*	*Resolution*	*Website*
BCC-CM1	Beijing Climate Center (China)	SRES A2 : 01/2000 – 12/2099 (run 1)	Atm: T63 L16 Ocn: T63 L30	http://bcc.cma.gov.cn/en/
BCCR-BCM2.0	Bjerknes Centre for Climate Research (Norway)	SRES A2 : 01/2000 – 12/2099 (run 1)	Atm: T63 L31 Ocn: 0.5-1.5˚ lat x 1.5˚ lon L50	http://www-pcmdi.llnl.gov/ipcc/model_documentation/BCCR_BCM2.0.htm
CCCMA-CGCM3.1	Canadian Centre for Climate Modelling and Analysis (Canada)	20C3M : 01/2000 – 12/2000 SRES A2 : 01/2001 – 12/2099 (runs 1-5)	Atm: T47 L31 Ocn: 1.875˚ lat x 1.875˚ lon L29	http://www.cccma.bc.ec.gc.ca/eng_index.shtml
CNRM-CM3	Meteo-France, Centre National de Recherches Meteorologiques (France)	SRES A2 : 01/2000 – 12/2099 (run 1)	Atm: T42 L45 Ocn: OPA 8.1	http://www.cnrm.meteo.fr/scenario2004/indexenglish.html
CSIRO-Mk3.0	Commonwealth Scientific and Industrial Research Organization (Australia)	SRES A2 : 01/2000 – 12/2099 (run 1)	Atm: T63 L18 Ocn: 0.925˚ lat x 1.875˚ lon L31	http://www.cmar.csiro.au/e-print/open/gordon_2002a.pdf
GFDL-CM2.0	NOAA Geophysical Fluid Dynamics Laboratory (USA)	20C3M : 01/2000 – 12/2000 SRES A2 : 01/2001 – 12/2099 (run 1)	Atm: N45 L24 Ocn: tripolar 360x200 L50	http://data1.gfdl.noaa.gov/nomads/forms/deccen/CM2.X/
GFDL-CM2.1	NOAA Geophysical Fluid Dynamics Laboratory (USA)	20C3M : 01/2000 – 12/2000 SRES A2 : 01/2001 – 12/2099 (run 1)	Atm: M45 L24 Ocn: tripolar 360x200 L50	http://data1.gfdl.noaa.gov/nomads/forms/deccen/CM2.X/
GISS-ER	NASA Goddard Institute for Space Studies (USA)	20C3M : 01/2000 – 12/2003 SRES A2 : 01/2004 – 12/2099 (run 1)	Atm: 4˚ lat x 5˚ lon L20 Ocn: 4˚ lat x 5˚ lon L13	http://www.giss.nasa.gov/tools/modelE/
INM-CM3.0	Institute for Numerical Mathematics (Russia)	20C3M : 01/2000 – 12/2000 SRES A2 : 01/2001 – 12/2099 (run 1)	Atm: 4˚ lat x 5˚ lon L21 Ocn: 2˚ lat x 2.5˚ lon L33	http://www.inm.ras.ru/en/
IPSL-CM4.1	Institut Pierre Simon Laplace (France)	SRES A2 : 01/2000 – 12/2099 (run 1)	Atm:2.5˚ lat. x 3.75˚ lon Ocn: 2˚ lat. x 2˚ lon (vicinity of the equator & in Med & Red seas 1˚ lat)	http://mc2.ipsl.jussieu.fr/simules.html

MIROC3.2 (medres)	Cent. for Clim. Sys. Res, Univ of Tokyo, National Inst. for Envir. Studies & Frontier Res. Cent. for Global Change (Japan)	20C3M : 01/2000 – 12/2000 SRES A2 : 01/2001 – 12/2099 (runs 1-3)	Atm: T42 L20 Ocn: 256x192 L44	http://www.ccsr.u-tokyo.ac.jp/kyosei/hasumi/MIROC/tech-repo.pdf
MIUB-ECHO-G	Meteorological Institute of the University of Bonn (Germany)	20C3M : 01/2000 – 12/2000 SRES A2 : 01/2001 – 12/2099 (runs 1-3)	Atm: T30 L19 Ocn: T42 + equator refinement L20	http://www-pcmdi.llnl.gov/projects/modeldoc/cmip/echo-g_tbls.html
MPI-ECHAM5	Max Planck Institute for Meteorology (Germany)	20C3M : 01/2000 – 12/2000 SRES A2 : 01/2001 – 12/2099 (runs 1-3)	Atm: T63 L32 Ocn: 1˚ lat. x 1˚ lon L41	http://www.mpimet.mpg.de/en/wissenschaft/ueberblick/atmosphaere-im-erdsystem/globale-klimamodellierung/echam/echam5.html
MRI-CGCM2.3.2a	Meteorological Research Institute (Japan)	20C3M : 01/2000 – 12/2000 SRES A2 : 01/2001 – 12/2099 (runs 1-5)	Atm: T42 L30 Ocn: 0.5-2.5˚ lat x 2˚ lon L23	http://www.mri-jma.go.jp/Welcome.html
NCAR-CCSM3.0	National Center for Atmospheric Research (USA)	SRES A2 : 01/2000 – 12/2099 (runs 1-5)	Atm: T85 L26 Ocn: gx1v3	http://www.ccsm.ucar.edu/models/ccsm3.0/
NCAR-PCM1	National Center for Atmospheric Research (USA)	SRES A2 : 01/2000 – 12/2099 (runs 1-4)	Atm: T42 L18 Ocn: 384x288 L32	http://www.cgd.ucar.edu/pcm/
UKMO-HADCM3	Hadley Centre for Climate Prediction, Met Office (UK)	SRES A2 : 01/2000 – 12/2099 (run 1)	Atm: 2.5˚ lat x 3.75˚ lon L19 Ocn: 1.25˚ lat x 1.25˚ lon L20	http://www.metoffice.com/research/hadleycentre/models/HadCM3.html
UKMO-HADGEM1	Hadley Centre for Climate Prediction, Met Office (UK)	SRES A2 : 01/2000 – 12/2099 (run 1)	Atm: N96 L38 Ocn: 0.3-1˚ lat x 1˚ lon L23	http://www.metoffice.gov.uk/research/hadleycentre/pubs/HCTN/HCTN_55.pdf

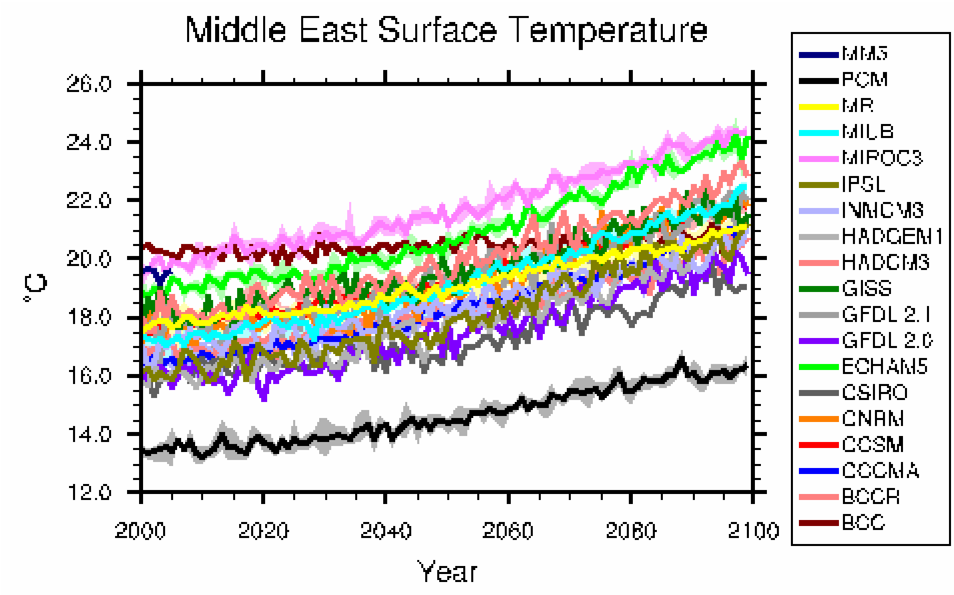

Figure 4. Same as Figure 1 but the the entire 21st century

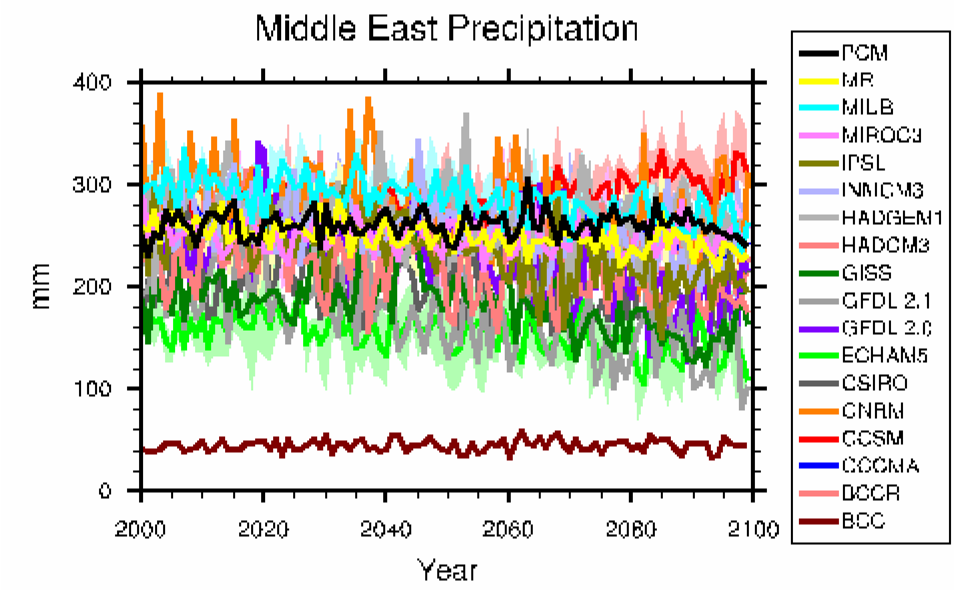

Figure 5. Same as Figure 2 but for the entire 21st century

Over the 21st century the GCMs (excluding PCM and BCC) predict an increase of temperature of ~4K with almost 75% of that occurring in the 2nd half of the century (Figure 4). There is almost no change in the overall inter-model variance in surface temperature. For precipitation there is a mean decrease of ~25mm however the main feature of the precipitation change is an increase in the inter-model variance with some models even showing a significant increase in precipitation (Figure 5). Again most of the change occurs in the 2nd half of the century.

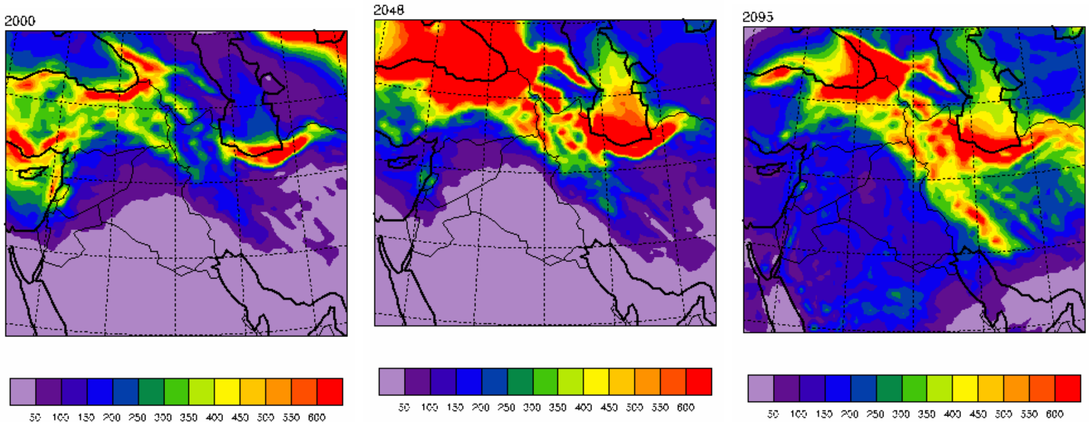

Figure 6. Mean annual precipitation from MM5

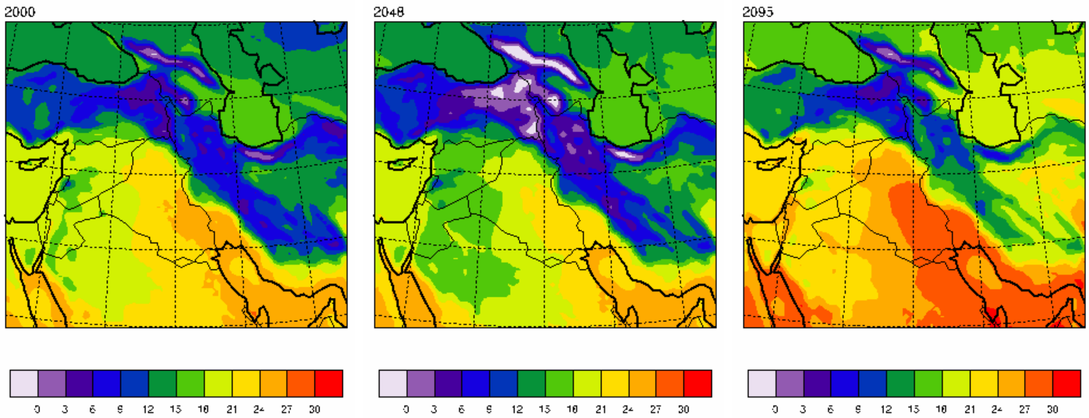

Figure 7. Mean annual temperature from MM5

Results from the regional climate model runs indicate in the distribution and amount of precipitation (Figure 6). By mid-century the model simulates a significant decrease in the Mediterranean region and a substantial increase in the Black Sea region. By the end of the century there is also a significant decrease in Western Turkey and an increase across the Southern portion of the domain. The simulated changes in temperature (Figure 7) do not reflect the monotonic increasing nature of the global predictions. At mid-century the model simulates a decrease in temperature especially in the Taurus and Caucasus mountains. This temperature decrease is caused largely by an increase in systems moving in from the North and North-West of the domain bringing cooler air and precipitating as snow rather than rain, allowing the snow-albedo feedback to further cool temperatures. By the end of the century the influence of these Northern systems to levels similar to that in the early century simulation and the overall temperature increase is more in line with global expectations. In the Euphrates-Tigris watershed these temperature increases and the associated increase in evapotransipiration do not account for the increase in precipitation predicted resulting in an increase in runoff.

CONCLUSIONS

Over the course of the 21st century the Middle East can expect to see a mean temperature increase of ~4K, while changes in precipitation remain highly uncertain. The change will not occur linearly through the century with the GCMs predicting the majority of the change to occur in the 2nd half. Results from a regional climate model amplify this non-linearity, actually simulating a decrease in temperatures by mid-century followed by a rapid increase. By the end of the century drying of Western Turkey and the Eastern Mediterranean and wetting over much of the rest of the domain is simulated. This increase in precipitation results in an increase in runoff in the Euphrates-Tigris watershed.

Acknowledgements
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SEASONAL FORECAST OF DANUBE RIVER FLOW ANOMALIES BASED ON ITS STABLE TELECONNECTIONS WITH THE GLOBAL SEA SURFACE TEMPERATURE AND PRECIPITATION FIELDS

Norel Rimbu[1], Constanța Boroneanț[2], Mihai Dima[1], Antoaneta Stanciu[3]

[1]Alfred Wegner Institute for Polar and Marine Research, Bremenhaven, Germany, nrimbu@awi-bremerhaven.de
[2]Bucharest University. Atmospherics Department National Meteorological Administration, Bucharest, Romania, boroneant@meteo.inmh.ro
[3]Bucharest University, Atmospherics Department National Institute of Hydrology and Water Management, Bucharest, Romania, antoaneta.stanciu@hidro.ro

ABSTRACT

Seasonal anomalies of river flows highly depend on large-scale fluctuations of atmospheric circulation. Heavy precipitation causing catastrophic floods in Central and South Eastern Europe became quite frequent in the last years after a long period of drought. Therefore, an outlook of river flows becomes an issue of an increasing interest and demand for policy makers and local administrations in order to prevent and mitigate flood consequences.

Using monthly data of Danube river at Orsova station (Romania) for the period 1840-1998 and global data of sea surface temperature (SST), air temperature (T) and precipitation (P) for the period 1901-2002 we present a method for a seasonal forecast of the Danube river flow anomalies. Our method is based on stable teleconnections of river seasonal flow anomalies with the global SST, T and PP fields. Key regions where the correlation is stable can be used as significant source of predictability for the river flow variability.

Significant potential predictability of spring flow anomalies using previous winter SST, T and PP anomalies from selected key regions was identified. We have also identified significant potential predictors for the Danube river anomalies in the fields of SST, T and PP anomalies for spring, summer and autumn, respectively. The potential predictors identified in this study can be used for the improvement of an operational forecast of the Danube river flow anomalies.

Key words: Danube river, Flow anomalies, Teleconnections, Seasonal forecast

EVALUATION OF RUNOFF AND PEAK FLOOD CHANGES FOR A PERIOD OF TIME

Mohammad Reza Yazdani[1], Sattar Chavoshi[2],Bahram Saghafian[3], Mehdi Vafakhah[4]

1, 2) Agriculture and Natural Resources research center of Isfahan, Iran
moreya1@yahoo.com
3) Soil conservation and watershed management research institute, Tehran, Iran
4) College of natural resources, Tarbiat Modarres University, Tehran

ABSTRACT

One of the most important problems in applied hydrology is runoff and peak flood estimation. This estimation with distinguished probability is used for structure design, such as storm sewage, erosion and flood control structure. In these cases probability of the flood is determined. Also is require to determining addition rate of runoff and peak flood that conservation works executed in watershed in based of this addition. One of these problems is evaluation of changes in watershed characteristics for a distinguished period. The factor that be used in this study was runoff curve number. If change percent of impervious land, soil hydrologic condition and land use, runoff curve number will be change. In this study changes in runoff curve number was evaluated based on rainfall-runoff data for a 15 years period and found that runoff and peak flood have increased for the same rainfall–runoff events in selected watersheds, except watershed 5. Potential of retention has decreased from 15 to 41 millimeters in this period. Average rate of runoff and peak flood addition in regions of 1 and 2 were 4.14 and 3.23, respectively that indicate high changes in conditions and characteristics of the selected watersheds.

Keyword: Peak flood change, Hydrologic condition, Watershed, Curve number.

INTRODUCTION

Development in scientific and engineering methods in water management is accelerated, but unclear problems are existence that requiring to more investigations. One of these problems is peak flood estimation in small watersheds, because lack of hydrometric stations (Hotchkiss, 1995; Mahdavi, 1999). Peak flood estimation and flood changes in a given period used in flood control, storm sewage design and weir design. However, determining real time of flood occurrence is difficult (Afshar, 1990; Najmaei, 1990).Peak flood can calculated regard to changes in watershed characteristics, such as impervious land, soil capacity, roads and vegetation. For this purpose, SCS runoff curve number can be used (Bonta, 1997; USDA, 1975; USDA, 1998). Regard to these changes in a watershed, curve number determined and runoff and peak flood have estimated. Changes in surface detention and storage in a watershed can use in flood control programs. Selection and capability of a method is depending on problem kind, date and runoff mechanism in a basin (Silviera, 2000). The goal of this study, was determining peak flood changes for a given time that used in comprehensive programs in small watersheds, especially for flood control.

Necessary works for control of these changes can have determined regard to future curve number and rainfall occurrence probability. For this purpose six watersheds in two regions of Iran were selected and then amount of the change in peak flood was evaluated after a 15 year period.

STUDY AREA

In this study, six watersheds were selected; 3 watersheds of Shomal region (north of Alborz mountains) and 3 watersheds of Azarbaiegan region. Mean annual rainfall varied from 300 to 1500 millimeters in shomal region. This parameter changes from 300 to 700 millimeters in Azarbayejan region (Khalili, 1983). Figure 1 shows two selected regions.

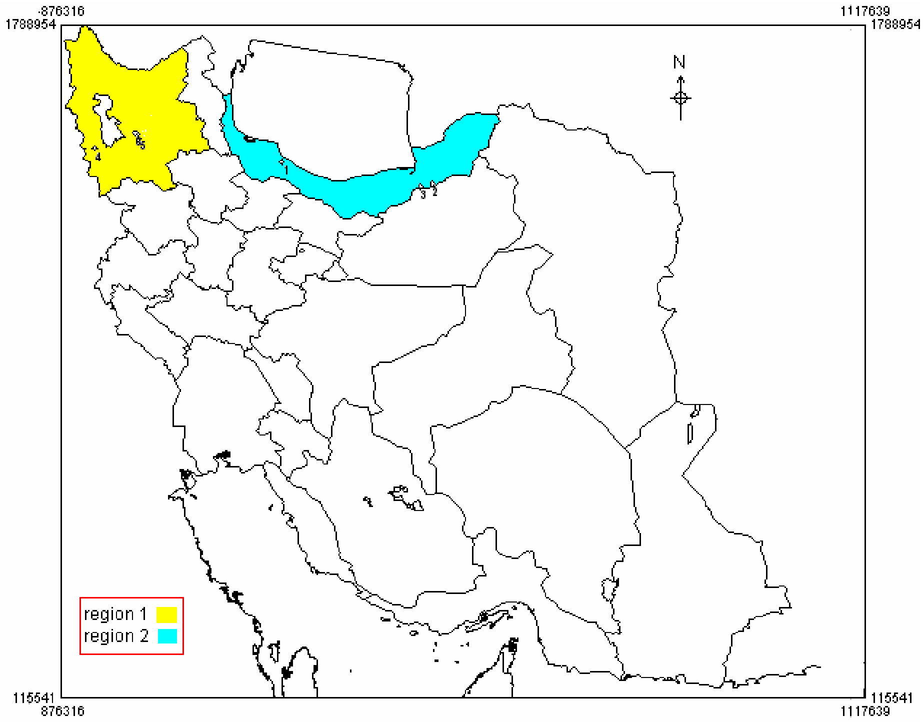

Figure 1. Location map of selected regions

METHODS

Some physiographic characteristics of selected watersheds were calculated using existence maps and information. Some physiographic characteristics of selected watersheds are summarized in table 1.

Table 1. Physiographic characteristics of selected watersheds.

Region	Watershed number	Station	River	longitude	latitude	Waterway length(Km)	Waterway slop	Area (km^2)
1	1	Samosh	Haratbar	50-18	36-59	21.5	15.3	102
	2	Nahar khoran	Nahar khoran	54-28	36-28	14	7.3	100
	3	Baghoo	Baghoo	54-09	36-44	10.6	16.6	22.7
2	4	Klazchi	Oshnoeieh	45-05	37-02	14.75	5.2	103
	5	Chekan chi	Chekan chi	46-19	37-21	24.5	3.65	103.7
	6	Mahpari	Khorma zard	46-10	37-26	9.4	3.6	88.75

Rainfall and peak discharge data were selected for each watershed based on a common period of time. This period was selected for 15 years (1980-1994) with attention to existence data. So changes in peak flood and runoff have evaluated in this period.

In the following, optimum curve number was determined in each watershed for rainfall-runoff paired data (P-Q) with the relation offering by Howkins (1985, 1998). In this relation, retention potential is calculating of the following relation:

$$S = 5(P + 2Q - \sqrt{4Q^2} + 5PQ) \qquad (1)$$

Where P is rainfall in millimeter and Q is runoff in millimeter.
In the next step, runoff curve number was obtained from the following relation:

$$CN = \frac{25400}{S + 254} \qquad (2)$$

Where, S is storage potential in millimeter.
Peak flood discharge was calculated of SCS method,

$$Q_{Max} = \frac{2.083AQ}{Tp} \qquad (3)$$

Where Qmax is peak flood discharge in cubic meter per second, A is area in square kilometer, Q is runoff depth in centimeter and Tp is time to peak in hour (Viessman, 1996).

RESULTS

With use of relations of 1 and 2, runoff curve number calculated in two period of time (5years), one period was selected 1980 to 1984 and the other period was 1990-1994. Average of curve number was calculated to gain optimum curve number in each watershed. These results are shown in table 2.

Table 2 . Curve number determining with rainfall-runoff Paired data in each watershed

Watershed	Date	Rainfall(mm)	Runoff(mm)	Detention potential(mm)	Curve number
1	1983.sep.14	108	2.1	381	40
	1984.oct.19	67	2.0	224	53
	1986.nov.5	72	2.3	237	52
	1993.sep.8	129	5.9	390	39
	1994.Jun.28	60	3.3	172	60
	1995.Jun.22	90	4.8	260	49
	1995.Jun.23	145	4.1	490	34
	1997.sep.5	30	2.0	81	76
2	1983.may.24	28	0.14	119	68
	1987.Aug.17	27	0.11	116	69
	1991.May.5	45	0.08	204	55
	1992.May.14	20	0.46	77	77
	1993.Sep.3	11	0.11	44	85
	1994.Apr.25	15	0.20	58	82
	1997.Jun.23	50	0.90	183	58
3	1984.Mar.9	19	0.09	81	76
	1986.Sep.17	31	0.30	123	67
	1993.Jun.23	39	1.40	125	67
	1994.Jun.4	20	1.2	56	82
	1995.Apr.24	24.5	0.6	85	75
	1997.May.5	16	1.20	41	86
4	1978.Mar.10	40	0.50	154	62
	1987.Apr.14	22	0.90	68	79
	1993.may.12	28	2.10	72	78
	1996.Apr.13	26	0.90	84	75
5	1987.Mar.11	9.5	0.75	24	91
	1994.May.1	15	1.00	40	86
	1997.Apr.28	13	1.05	33	88
6	1986.May.3	9	0.60	24	91
	1984.Apr.13	37	1.50	115	69
	1985.Apr.3	16	0.50	53	83
	1992.Apr.22	19	0.80	58	81
	1993.May.13	13	0.82	36	88
	1994.Apr.2	17	0.50	57	82
	1995.Apr.12	16	0.64	50	84
	1996.Apr.14	8	0.23	27	90

In the next step, average of curve number was calculated for two periods of 5 years using calculated curve number. This result is presented in table 3.

Table 3. Average curve number for two periods of time in selected watersheds

watershed	Curve number		ΔCN
	First period(1980-1984)	Second period(1990-1994)	
1	48	52	4
2	68	71	3
3	72	78	6
4	71	77	6
5	91	87	-4
6	81	85	4

Change in hydrologic condition was determined in this period with table of curve number determination that offering by Natural Resources Conservation Service of the United State Agriculture. Table 4 shows change in hydrologic condition in selected watersheds. It should be consider that the table has descriptive concepts.

Table 4. change in hydrologic condition in selected watersheds

watershed	Primary hydrologic condition	secondary hydrologic condition
1	A	B
2	B	C
3	B	C
4	B	C
5	D	C
6	C	D

Changes in storage potential were calculated with use of average curve number in each period and relation 2. These results are presented in table 5.

Table 5. Storage potential calculation in two given period

watershed	Primary retention potential(mm)	Secondary retention potential(mm)	Retention potential changes	Change%
1	275	234	41	-14.9
2	119.5	103.7	15.8	-13.1
3	98.7	71.6	27	-27.4
4	103.7	75.9	27.8	-27
5	25.1	37.9	12.7	+51
6	59.6	46.8	14.8	-24.8

In continue maximum flood discharge was calculated using rainfall in primary period and calculated curve number in second period. Then amount of change in peak flood was distinguished in this period. Results are depicted in table 6. Average rate of addition in runoff and peak flood are depicted in table 7 for each watershed.

Table 6 . Determining increment rate in peak flood for a given period

watershed	Rainfall(mm)	Qpeak1(m^3/sec)	Qpeak2(m^3/sec)	Qpeak2/ Qpeak1
1	108	44	262.4	5.96
	67	43.2	33.2	0.76
	72	47.1	47.1	1
2	28	3.08	9.98	3.24
	27	2.46	7.22	2.93
3	19	0.77	2.36	3.06
	31	2.4	25.21	10.5
4	40	9.16	112.02	12.22
	22	17.82	10.63	0.59
5	9.5	8.75	1.48	0.17
6	9	11.58	3.11	0.27
	37	29.4	210	7.14
	16	9.5	18.6	1.95

Table 7. Average rate of addition in peak flood in two regions.

Region	Watershed	Average rate of increment in peak flood	Average rate of increment in peak flood(regional)
1	1	2.57	4.14
	2	3.08	
	3	6.78	
2	4	6.4	3.23
	5	0.17	
	6	3.12	

CONCLUSION

Results indicate curve number has increased in all watersheds except watershed 5 that it displays change in condition and characteristics of selected watersheds. Runoff generation potential was increased during the 15 years period. Average addition in runoff curve number was 4 in selected watersheds. Hydrologic conditions declined about one group in all watersheds except watershed 5, regard to stability in other conditions. Regard to table 3, detention potential was declined in all watersheds except watersheds 5.This reduction was among 15 to 41 millimeters (13 to 27 percent). Also the peak flood increased highly in this period, that indicating intense changes in the watersheds and these changes affect runoff rising and reduction of concentration time of the watersheds. Peak flood discharge has increased after a 15 years period, intensively. Addition rate of peak flood was from 0.17 to 12.2 in the watersheds in spite of Watershed 5 that has dropping rate. Potential of runoff generation was decreased because of two reasons: first, it maybe because of an error in collection and register of data in hydrometric station and secondly it can because of performance suitable protection and management works such as flood control structures in watersheds. Whereas it is require to more investigations. Average addition rate in peak flood discharge was from 2.57 to 6.7 in selected watersheds. This rate for two regions was 4.14 and 3.23 respectively.

With use of this method we can predict peak flood discharge in future years. We can determine changes in watershed characteristics such as soil hydrologic condition, land cover, vegetation, impervious land and etc, and then predict runoff curve number in future year regard to these changes. Detention potential and peak flood discharge can be estimated with use of curve number and probable maximum precipitation and then necessary works will be programmed for erosion and flood control. Results indicate unsuitable management in selected watershed. A few factors were caused high addition in runoff for a short time (15years), such as road creating, degradation of vegetation and forests, urban developing in watershed, unsuitable land use an so on. To control of these additions is requiring structure and other protection works that these have high cost. As a result, use of runoff curve number for change estimation in runoff generation potential can be use in management functions in a watershed.

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POSSIBLE EFFECT OF THE GLOBAL CLIMATE CHANGE ON WATER RESOURCES AND FLOODS IN TURKEY

M.Sait Tahmiscioglu[1], Omer Karaca[2], A.Deniz Ozdemir[2], Hamza Ozguler[3]

[1] General Directorate of State Hydraulic Works, DSI, Deputy Head, Investigation and Planning Depatment
[2] General Directorate of State Hydraulic Works, DSI, Project Hydrology Section
[3] General Directorate of State Hydraulic Works, DSI, Office of International Hydrological Relations

ABSTRACT

Nowdays the topic of the climate change and its negative effects on human life are being studied all over the world. There are many publications and various evaluations in this respect. On the other hand, scientific research studies on this issue are still going on. The most important aspect of these studies is the negative effects of the climate change on water resources.

In this study, briefly evaluating the country's water resources and taking into account of climate change projections for he whole region, the authors have studied the effect of the climate change on water resources and floods .

Key Words: Climate change, water resources, floods.

WATER POTENTIAL OF TURKEY

Of 501 billion m^3 of annual precipitation, 274 billion m^3 is assumed to evaporate from surface and transpire through plants. 69 billion m^3 of precipitation directly recharges the aquifers, whereas 158 billion m^3 forms the precipitation runoff. There is a continuous interaction between surface runoff and groundwater, but it is estimated that a net 28 billion m^3 of groundwater feeds the rivers. So, average annual surface water potential is 186 billion m^3, with the surface runoff of 7 billion m^3 coming from neighboring countries, total surface runoff within the country reaches 193 billion m^3. However, not all of the renewable water resources can be utilized because of economic and technical reasons. Exploitable portions of surface runoff, inflow from bordering countries, and groundwater are 95, 3, and 12 billion m^3, respectively. Thus, the total of exploitable water resources amount to 110 billion m^3 (Table 1).

Table 1. Gross total amount and consumable water in Turkey

SURFACE WATER	RAINFALL (mm)	WATER AMOUNT (billion m^3/year)	GROSS WATER POTENTİAL (billion m^3/year)	EXPLOİTABLE (billion m^3/year)
TURKEY	643	501	186	95
FROM BORDERİNG COUNTRİES			7	3
GROUNDWATER			41	12
TOTAL			**234**	**110**

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SECTORAL WATER DEMAND

It is estimated that together with mainly DSİ and other governmental institutions and private sector will be able to offer 110 billion fresh water to the consumption of various sector by developing additional project by the year 2030. For realizing this aim, Financial resources should be incresed year by year.

Gross irrigable area of Turkey is 8,5 million hectares. The aim is to start to irrigate the whole of this area until 2030. Water requirement for this area will be 71,5 billion m^3. From 2000 to 2030, In total consumption, the pecentage of the irrigation will drop from 75 to 65 %.

According to the estimations of population growth rate, although the growth rate of population is decrasing year by year, Turkey's population will reach to 110 billion in 2030. per capita available water was 250 litre/day in 2000. With the assumption of Turkey will develope, this amount will increse and become 500 litre/day in 2030. So Turkey will have reached to the present value of the Europen Union. Furthermore, ıt is estimated that tourism sector will neeed 5 billion m^3 of water in 2030. So, the total water requirement for domestic consumption will be 25,3 billion m^3.

Industry sector used 4,2 billion m^3 of water in 2000. But with the increasing rate of % 4 for every year, water demand of industry sector will become 13,2 billion m^3 (Table 2).

Table 2. Sectoral water consumption in Turkey (DSI, 2003).

YEAR	TOTAL WATER CONSUMPTİON		SECTORES					
			IRRIGATION		DOMESTİC USAGE		INDUSRY	
	km^3	%	km^3	%	km^3	%	Km^3	%
1990	30,6	28	22,0	72	5,1	17	3,4	11
2000	39,3	36	29,3	75	5,8	15	4,2	10
2030	110,0	100	71,5	65	25,3	23	13,2	12

CLIMATE CHANGE

In addition to natural variability, some of human activity (industry, transportation, energy production and consumption etc.) has started to affect the earth climate. These activities has produced large amount of greenhouse gases. Accumulation of these gases, deforestration and incresing of land use has caused to tend to increase the mean temperature of the earth.

According to the IPPC report of 2001, The global average surface temperature has increased by approximately 0,6±0,2 ^{0}C since the late 19 th century (IPPC TAR Chapter 2). It is also satated that greenhouse gases has been the main reason of global warming during the last 50 year. It is very likely that 1990s warmest decade and 1998 the warmest year in the instrumental record in the period of 1860-1996. According to the updated records, 2001 was the second warmest year and it has a positive anomaly of 0,42 ^{0}C.

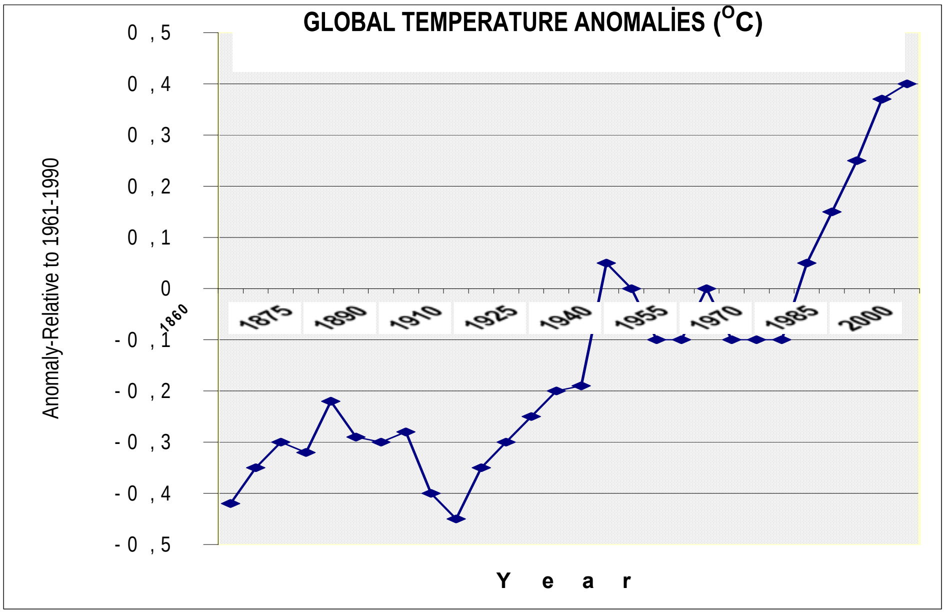

Figure 1. Annual anomalies of global average land surface air temperature (IPCC).

Figure 1 shows the anomalies of the mean temperature of the world. These anomalies are of the deviations from the average of 1961-1990. Values are the simple averages of the anomalies for the two hemisphere. It is very likely that precipitation has increased by 0,5 to 1 % per decade over most mid and high lattitude of the northern hemisphere. It is also likely that rainfall has decreased over much of the northern hemisphere subtrpical (10^0 N to 30^0 N) land areas by about % 0,3 per decade during the 20 th century. It is likely that there has been 2 to 4 % increase in heavy precipitation events in the same areas.

CLIMATE CHANGE SCENARIOS

The global surface temperature is projected to increase by 1,4 to 5,8 ^{0}C over the period 1990 to 2100. Global average water wapour concentration and precipitation are projected to increase during the 21 st century. By the second half of 21 st century it is likely that precipitation will have increased over northern to high lattitudes in winter. The return period for extreme precipitation events decreases almost everywhere. At low latittitudes there are both regional increases and decreases over land areas. It is also likely that more intense precipitation events will have increased over many northern hemisphere mid to high lattitude land areas. Snow cover and sea-ice extent are projected to decrease. Global mean sea level is projected to rise by 9 to 88 cm over the period 1990 to 2100 (IPCC).

According to the same projections, in Mediterranean region which comprises Turkey, average temperature is projected to icrease by 2 ^{o}C in winter and 2-3 ^{o}C in summer. Precipitation will have decreased by 15 to 25 % in summer. But it will have increased by 5 to15 % in winter. Soil moisture will have decreased by 5 to 15 % and sea level will have raised by 35-65 cm (IPCC).

EFFECT OF THE CLIMATE CHANGE ON WATER RESOURCES IN TURKEY

Streamflow is the main factor of the water resource. Changing in flows based on the precipitation mostly. But some other parameters, such as land use, deforestration and vegetation may be more effective than climate change (IPCC). These parameters may also change the characsteristics of a basin and flow conditions. There are a few study implemented on this subject. Flow measurement values taken from gauging stations of the various streams had been used in these studies. It was stated that especially average and low flows had decreased slightly in western, interior and south part of Turkey. Statistically significant change had not been seen in the other part of Turkey (Cığızoğlu at all, 2004). In another study, it was stated that except for the 13 th, 22 th (in the Black Sea region) and 23 th basins (in the North east of Turkey) there is a slightly decrease in flows in the other regions of Turkey. This decrease shows difference from one region to another. But the trends of decrease are especially notable in Marmara and Aegean regions (Angı at all, 2004).

In Mediterranean region, the rate of snow melting/evaporation is higher than the surrounding regions. As a result of this sitiuation , especially in eastern region of Turkey, water levels of the streams and dam reservois don't rise even though it snows as much as old times (Kadıoğlu, 2001). Additionally, Japan Meteorology Agency states that the intensity of drought has been increasing in the period of September-December in the Mediterranean region. Related to this knowledge, Figure 2 given by Arnell, shows the effects of climate change on water resources of some countries.

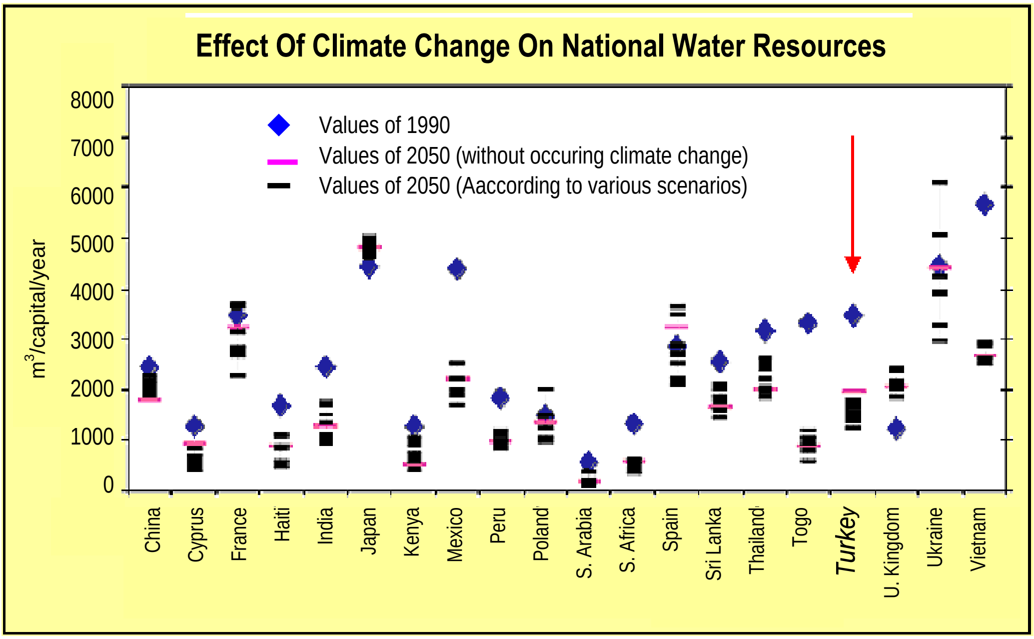

Figure 2. Change of water resources of some countries (Arnell, 2000).

Figure 2 shows that the changes of water amount in various countries in (a) 1990, (b) 2050-without occuring climate change, (c) 2050-according to the varous climate change scenarios. As seen from figure 2, like many other country, water amount in Turkey will have been decreased very seriously by 2050. Per capita availability of potential water resources is 3070 m^3/year in 1990, which is high fort he Middle East. However, water resources are not evenly distributed in Turkey. Even if we assume that climate conditions are stable, due to the growth of the population of Turkey, per capita of water potential will be 1240 m^3/year. When climate change is taken into account, by the year 2050, per capita of water potential will be 700-1910 m3/year in Turkey (Kadıoğlu, 2001).

According to the climate change scenarios, the impacts of the climate change can be generalised as following;

- Precipitation will increase slightly in winter, conversely it will decrease in summer.
- Seasonal distribution and intensities of precipitation will change.
- Snow cover have been decresasing since 1987. This state will continue.
- In project studies, snow-line should be updated.
- Not only will the water amount in streams decrease, but their peak times will change .
- Frequency and intensity of drought and flood induced loses will increase
- Because of the water stress to which water defict is caused will increase nation wide.
- Uncertainties will occour in water supply studies. That is why cost of projects will increase.
- Importance of small dams will increase.
- More realistic prices should be fix.

EFFECTS OF THE CLIMATE CHANGE ON FLOODS IN TURKEY

It is well known a fact that climate change is among the trigger agents of unusual floods. It causes changes in timing, regional patterns and intensity of precipitation events, and in particular, in the number of days with heavy and intense precipitation occurences. Floods are now being experienced in areas where there were no floods in the past. This may be linked to the regional effects of the global climate change.

The potential for increased flooding following climate change would be exacerbated by erosion associated with deforestation and overgrazing both of which are now very widespread in many parts of Turkey. Such environmental degradations also increase surface runoff and the severity of flooding and contribute to landslides.

Although the possible relationship between floods and climate change, exacerbated by erosion associated with deforestation and overgrazing, has often been mooted, it is unclear to what extent the two can be linked. Ultimately, the climate change component has an incremental effect, likely to make extreme floods more frequently in some areas in Turkey. Nevertheless, not all floods can be attributed to climate change.

As seasonal fluctiotions in flows are more sensitive to air temperature than other parameters in Mediterranean region, flows are mainly affected by warming (Kadıoğlu, 2001). But in general, changes in annual streamflow relate well to changes in total precipitation (IPCC). In this region very heavy rainfall may occour and cause destructive flood events. The flood coefficient that is described as the rate of peak flow to mean annual flow is higher than other regions (Figure 3).

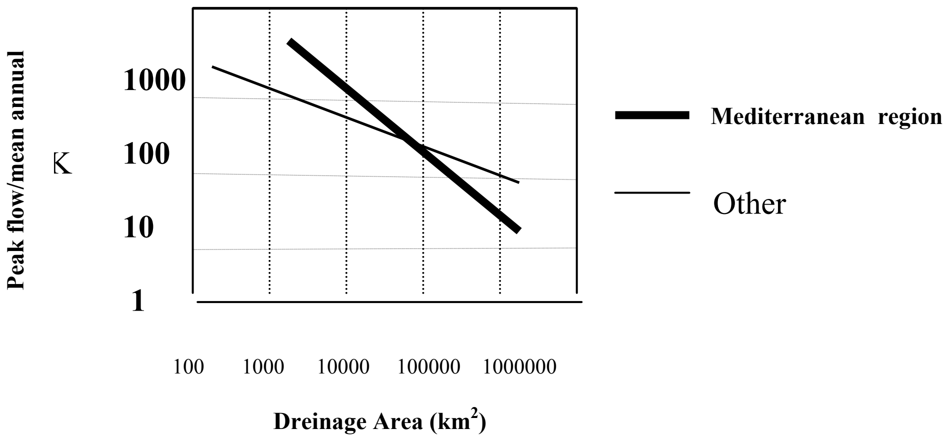

Figure 3. The flood coefficient, in Mediterranean and other regions (Prieto, M.).

Flash floods occur rather often in Mediterranean region. Turkey often undergoes affects of natural disasters. It can be seen that the number of floods and flash floods has been getting more and more (Figure 3). Smilarly, flood events have increased in Europe in the period of 1975-2001 too. In Turkey, flooding is the second important natural hazard after the earthquakes, with 22 floods and 19 deaths per year on average (Figure 4).

Some information of the floods of last two decades, from 1980 to 2002, in Turkey are shown in Figure 5. In some individual years, for example 1995, the monetary values of the total annual losses caused by floods reached up to 0,5 % of the total real Gross Domestic Product (GDP) of the country. In addition, floods cause the highest monetary loses among natural disasters. Figure 2 shows that flood-induced monetary losses rising up to a few billion-dollar range (Figure 5)

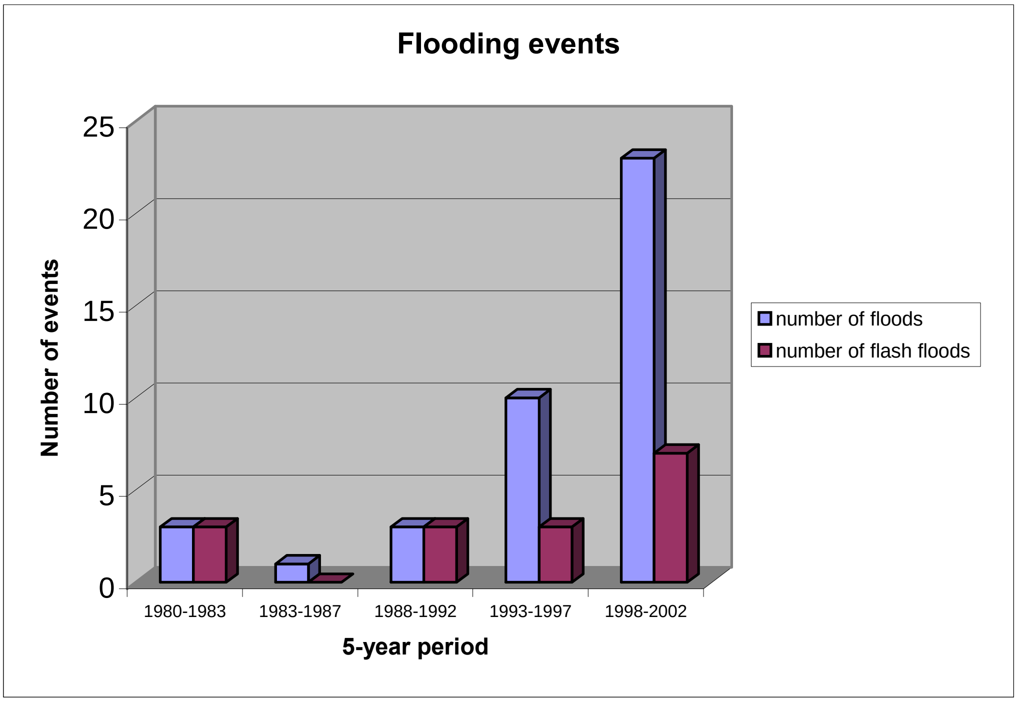

Figure 4. The number of floods in last decade (Özgüler, 2003).

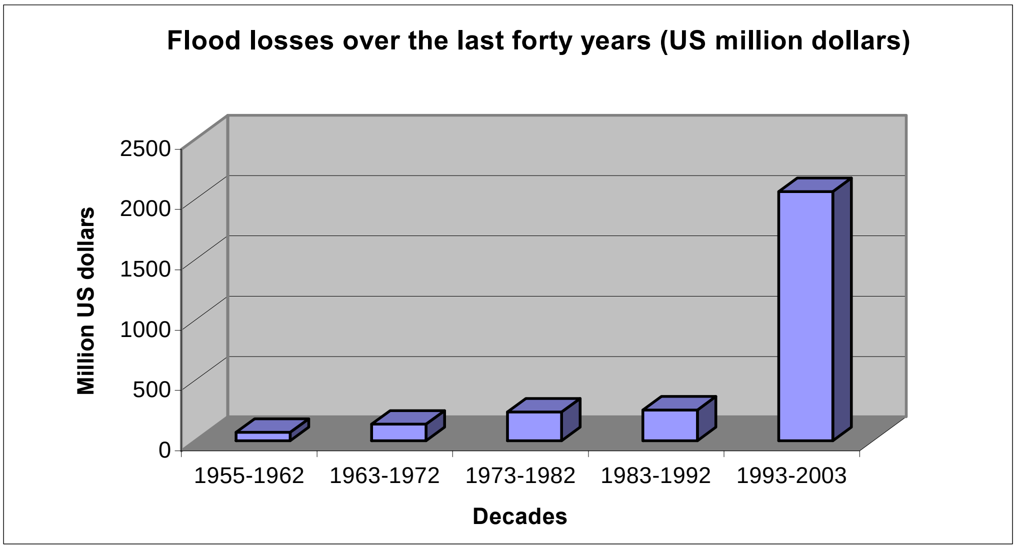

Figure 5 . Flood-induced monetary loses in Turkey (Özgüler, 2003).

CONCLUSION

Some regions of Turkey will likely feel more the effects of the drought in future. In basin planning, water resources and agricultural areas should be considered as a whole. To do this, groundwater resources should be managed better.

Under the effect of the changing climate, water balance analyses, climate change projections and drought monitoring studies should be done and various management plans should be prepared.

To estimate the situation of the water resources in future, changes in land use and vegetation should be monitored and evaluated. For his purpose investigation studies should be increased.

Impacts of the climate change should be taken into account in reservoir operation studies.

Agricultural areas of Turkey should be detemined considering the conditions of climate, soil, and water.

Dams and hydroelectric power plants should be prefered as a source .

People shoul be educated on the topics of water saving and using the water more carefully.

To determine the regional effects of climate change in Mediterranean region, related countries should work together, such as Med-Hycos and Friend-Ahmy projects.

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MODELING FOR CLIMATE CHANGE EFFECTS IN THE GEDIZ AND BUYUK MENDERES RIVER BASINS

Okan Fistikoglu, Sevinc Özkul, Nilgun Harmancioglu

Dokuz Eylul University Water Resources Management Research Center (SUMER)
Izmir, Turkey, okan.fistikoglu@deu.edu.tr

ABSTRACT

The presented paper summarizes the results of the studies on "Modeling for Climate Change Effects in the Gediz and Buyuk Menderes River Basins under the UNDP-GEF Project: Enabling Activities for the Preparation of Turkey's Initial National Communication to the UNFCC". The purpose of this sub-project is the "provision of preliminary assessments regarding the possible impacts of global climate change on water resources". The studies cover the generation of climate change scenarios, modeling of basin hydrology, and testing the sensitivity of runoff to changes in precipitation and temperature

INTRODUCTION

Dokuz Eylul University Water Resources Management Research Center (SUMER) was assigned in 2005 the task of carrying out studies on "Modeling for Climate Change Effects in the Gediz and Buyuk Menderes River Basins under the UNDP-GEF Project: Enabling Activities for the Preparation of Turkey's Initial National Communication to the UNFCC". The purpose of this sub-project was defined as "provision of preliminary assessments regarding the possible impacts of global climate change on water resources", as hydrologic systems and water resources are likely to be seriously affected by global climate change.

Since precipitation and temperature are the major climatic inputs to a hydrologic system, the first part of the project covers investigations into changes that may be expected in these variables due to climate change. Two approaches are used for this purpose: (a) trend analyses are performed on observed precipitation, temperature and runoff data of selected hydro-meteorological stations in each basin; (b) for the same set of data used in trend analyses, various types of GCMs are run to estimate likely changes in precipitation and temperature for two SRES emission scenarios.

The second part of the project is designed to focus on prediction of changes in hydrologic processes, i.e., evapotranspiration and runoff, which result from estimated changes in precipitation and temperature. The steps of this analysis cover: (a) generation of climate change scenarios to estimate changes in precipitation and temperature for each basin; (b) application of these changes to the basins through a downscaling procedure and a basin water balance model to estimate changes in output variables of evapotranspiration and runoff; (c) testing of the sensitivity of runoff to changes in precipitation and temperature.

DESCRIPTION OF TEST CASES: GEDIZ AND BUYUK MENDERES BASINS

The case study focuses on two major and closely located river basins in western Anatolia along the Aegean Sea (Figure 1). The first one is the case of the Gediz River Basin, which is the second largest basin in the region with a total drainage area of about 18000 km^2. The most significant feature of the Gediz Basin is water scarcity, which is due basically to competition for water among various uses, mainly irrigation with a total command area of 110,000 ha versus the domestic and fast growing industrial demand in the coastal zone, and environmental pollution although the basin experiences droughts from time to time. Current analyses on hydrologic budget of the basin indicate that the overall supply of water for various uses is almost equal to the overall demand. Practically, this means that there is no reserve for further water allocation in Gediz.

The second case considered is the Buyuk Menderes, which is the longest river in the Aegean region. It meanders for 584 km through western Turkey before reaching the Aegean Sea with a large delta, consisting of several lagoons, extensive salt steppes and mudflats (the biggest in Turkey). The Buyuk Menderes Delta is an important wetland with an area of 9800 ha; like Gediz Delta, it is recognized as a RAMSAR site. Buyuk Menderes has a total drainage area of 24976 km^2, and the annual runoff is in the order of 3 km^3, which accounts for 1.6% of Turkey's water potential.

Figure 1. Gediz and Buyuk Menderes basins along the Aegean coast of Turkey.

The basin is engineered into extensive water resources systems, including 13 dams and a large number of irrigation schemes. The total irrigated area in the basin is more than 88000 ha. The region is rich not only in terms of agriculture but also in industry, the major one being the textile industry, and tourism. These activities indicate significant demand and competition for water.

TREND ANALYSES

As a preliminary investigation of possible changes in climatic variables of the two basins, trend analyses are applied to observed surface runoff series and selected precipitation and temperature time series at major stations. These analyses comprise testing of significant correlation between observed records versus time by using parametric (Pearson's r) and non-parametric (Spearman's rho) methods. Trend analyses are applied on the observed data of selected meteorological (precipitation and runoff) (Table 1) and hydrologic (runoff) gauging stations (Table 2), the locations of which are given in Figure 2. For trend analyses of runoff series observed at streamgaging stations in the Gediz and Buyuk Menderes Basins, representative stations, which are free of the effects of upstream flow regulations, were selected to cover the entire watersheds.

Table 1. Selected meteorological stations.

	Station Name	**Variable**
Gediz Basin	Menemen	Daily Precipitation
	Manisa	Daily Precipitation
Buyuk Menderes Basin	Uşak	Daily Precipitation
	Aydın	Monthly Precipitation
	Denizli	Monthly Precipitation

Table 2. Selected streamgaging stations.

Stations in Gediz Basin		**Stations in Buyuk Menderes Basin**	
EIE509	EIE523	DSI714	EIE701
EIE514	EIE524	DSI730	EIE712
EIE515	EIE525	DSI737	EIE725
EIE522	EIE527	DSI771	EIE733

All precipitation time series of the Gediz Basin show a significant decreasing linear trend over the entire period of records. Temperature time series also reflect significantly increasing trends. Thus, it is expected that the basin runoff should decrease over time since the main input of runoff, i.e. precipitation, decreases, and the major loss from runoff, or evapotranspiration increases as the temperature increases. This expectation is confirmed by the detection of statistically meaningful decreases in runoff series. In contrast, the precipitation records of the Buyuk Menderes Basin do not show any statistically significant decrease despite the decreasing trends observed. The historical temperature series also indicate a negative slope for the regression line, even though the statistical tests reject the presence any significant trend. Despite the insignificant decreases in precipitation and temperature, the results of trend analyses on the historical runoff series over the basin reveal statistically significant decreases.

The trend analyses of the runoff time series observed at a total of 16 stream gauging stations in the Gediz and Buyuk Menderes Basins disclose statistically meaningful decreasing trends, which may lead to serious water supply/demand problems in the future. Thus, the possible effects of climate change at regional scale in each basin would be to enhance the already existing water scarcity and water allocation problems. This, in turn, will worsen the current conflicts, which have already started due to the high anthropogenic activities in both basins, among water users.

GENERATION OF CLIMATE CHANGE SCENARIOS

Climate change effects in spatially averaged temperature and precipitation over Gediz and Buyuk Menderes River Basins are assessed using a new version of the MAGICC/SCENGEN model, developed by NCAR-CRU using over a dozen recent GCMs. MAGICC/SCENGEN is a coupled gas-cycle/climate model (MAGICC) that drives a spatial climate change scenario generator (SCENGEN). MAGICC is a Simple Climate Model that computes the mean global surface air temperature and sea-level rise for particular emissions scenarios for greenhouse gases and sulphur dioxide **[1]**.

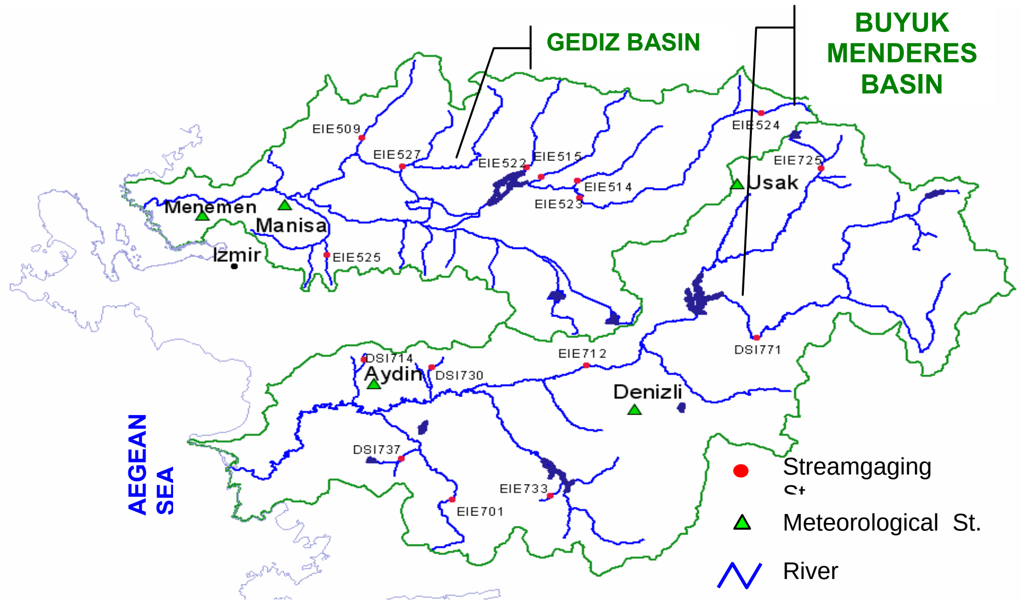

Figure 2. Locations of the selected meteorological and streamgaging stations.

The 49 emission scenarios involved in MAGICC model are investigated; and the ASF model of A2 and MESSAGE model of B2 storylines, which represent the marker scenarios of IPCC SRES, are selected to evaluate climate change effects in the case basins. On the other hand, there are 17 different GCM models in the SCENGEN package, which are run simultaneously to find the total error between the generated and the observed values of temperature and precipitation. Next, to determine the best combinations of the GCMs, alternative model runs are realized, and the best combinations of the GCMs are selected as those which have minimum error terms for each variable (temperature and precipitation) and for each period (annual, seasonal and monthly). Then, these combinations are employed to generate changes in temperature and precipitation in the regions investigated.

In the next step, the above global change scenarios are downscaled to the regional scale by using SCENGEN. In the regional analysis, the changes in the temperature and precipitation are examined on annual, seasonal (four seasons) and monthly (12 months) bases. The procedure is repeated for both emission scenarios, i.e., A2-ASF and B2-MESSAGE and for three projection years of 2030, 2050 and 2100. The IPCC SRES B2 scenario assumes a world of moderate population growth and intermediate level of economic development and technological change. SCENGEN estimates a global mean temperature increase of 0.85 °C by 2030, 1.33 °C by 2050, and 2.48 °C by 2100. The IPCC SRES A2 scenario assumes a world of high population growth and intermediate level of economic development and technological change. SCENGEN estimates a global mean temperature increase of 0.67 °C by 2030, 1.29 °C by 2050, and 3.47 °C by 2100. The estimated changes in temperature and precipitation are summarized in Tables 3 through 6.

According to the results of the scenarios, B2-MESSAGE and A2-ASF, it can be concluded that an increase of 1.2 ^{0}C in mean annual temperature, and a decrease of 5% in mean annual precipitation may be expected for the year 2030. In 2050, the mean annual temperature increases around 2 ^{0}C, and mean annual precipitation decreases around 10%. On the other hand, due to the assumptions of the applied GCMs, in the year of 2100, the range of temperature and precipitation estimates has a steep deviation than previous ones, so that any interpretation on the estimated values for this year is not preferable.

Table 3. Generated Changes in Temperature under the IPCC B2-MES Scenario.

Period	Baseline			2030		2050		2100	
	Observed	Modeled							
	Mean	Mean	Std.	Change	Ch. in Var.	Change	Ch. in Var.	Change	Ch. in Var.
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
	^{0}C	^{0}C	^{0}C	^{0}C	%	^{0}C	%	^{0}C	%
Annual	16.3	16.4	0.4	**1.2**	5.1	**1.8**	7.9	**3.2**	14.7
DJF	9.4	9.4	0.8	**1.0**	-2.5	**1.5**	-3.9	**2.6**	-7.2
MAM	14.4	14.4	0.6	**1.1**	2.7	**1.7**	4.1	**2.9**	7.7
JJA	23.4	23.5	0.6	**1.6**	3.8	**2.4**	5.9	**4.1**	10.9
SON	17.8	17.8	0.8	**1.4**	-2.0	**2.0**	-3.1	**3.6**	-5.7
January	8.7	9.0	1.4	**0.9**	1.1	**1.4**	1.7	**2.5**	3.1
February	9.2	9.3	1.2	**0.9**	5.6	**1.3**	8.8	**2.4**	16.4
March	10.9	10.9	1.0	**0.8**	-4.6	**1.2**	-7.2	**2.1**	-13.4
April	14.2	14.3	0.8	**1.1**	0.6	**1.6**	0.9	**2.7**	1.8
May	18.0	17.9	0.9	**1.4**	7.1	**2.1**	11	**3.7**	20.5
June	21.8	21.9	1.1	**1.6**	5.1	**2.3**	7.9	**4.1**	14.8
July	24.1	23.9	0.8	**1.6**	-0.5	**2.3**	-0.7	**4.1**	-1.3
August	24.4	24.4	0.8	**1.7**	-1.1	**2.6**	-1.6	**4.5**	-3.1
September	21.7	21.6	0.8	**1.5**	1.5	**2.2**	2.3	**3.8**	4.3
October	17.8	17.8	1.1	**1.4**	2.5	**2.1**	3.9	**3.7**	7.3
November	14.0	13.8	1.1	**1.1**	0.4	**1.6**	0.6	**2.7**	1.1
December	10.4	10.5	1.3	**1.0**	-3.2	**1.5**	-4.9	**2.6**	-9.2

Column1: Obs.Base. This is observed climate for the base period. SCENGEN uses the globally complete CMAP **[2]** precipitation and CRU **[3]** temperature climatologies.
Column2: Mod.Base: The model simulation of 1990 climate (base).
Column3: S.D.Base: Standard deviation (interannual variability) of the present-day climate as simulated by the selected GCM/GCMs..
Column 4-6 and 8: Change: Change in variable for the time period selected relative to 1990. This could be added to the observed climate data to produce the downscaled climate scenario.
Column 5-7 and 9: S.D.Change: Percentage change in standard deviation of the selected climate variable simulated by the GCMs.

In the context of the Model estimations, the increase in the monthly temperatures indicate that warmer winters are expected, while the summers get hotter. Although decreases are expected in precipitation in all months, the sharp decreases in spring and autumn months are significantly important, because the summer seasons in the region are already dry.

ASSESSMENT OF THE IMPACT OF CLIMATE CHANGE ON HYDROLOGY AND WATER RESOURCES

Global warming due to the greenhouse effect is expected to cause changes in meteorological conditions **[4]**. Generally, climate change or its increased variability is expected to alter the timing and the magnitudes of such processes as precipitation, evapotranspiration and runoff. As a result, regions where floods occur rarely may encounter more frequent events of high flows, while droughts and water scarcity may intensify in other regions **[5, 6]**. Thus, the need is indicated to evaluate the impact of expected climate change on hydrology and water resources at regional and local levels by the use of GCM and hydrologic models **[7]**.

In this section, the selected GCM scenarios of the previous step are analyzed at regional scales by means of a parametric water budget simulation model to observe the effects of temperature and precipitation changes on runoff in the Gediz and Buyuk Menderes river basins. The model, based on the modified Thornthwaite water balance model, operates on a monthly basis with precipitation (P) and potential evapotranspiration (PET) as input variables. Model parameters to be calibrated are: maximum soil moisture SMAX (mm), watershed lag coefficient SSRC, groundwater reservoir coefficient GWRC, and storm runoff coefficient SRC. The output variables are the modeled runoff Q (mm) and soil moisture S (mm). In this model, potential evapotranspiration (PET) is defined as an exponential function ($PET=Ae^{Bt}$) of temperature, using two additional parameters A and B.

Table 4. Generated Changes in Temperature under the IPCC A2-ASF Scenario.

Period	Baseline			2030		2050		2100	
	Observed	Modeled							
	Mean	Mean	Std.	Change	Ch. in Var.	Change	Ch. in Var.	Change	Ch. in Var.
	1	2	3	4	5	6	7	8	9
	^0C	^0C	^0C	^0C	%	^0C	%	^0C	%
Annual	16.3	16.4	0.4	**1.2**	4.0	**2.0**	7.7	**4.4**	20.6
DJF	9.4	9.4	0.8	**1.0**	-2.0	**1.6**	-3.8	**3.5**	-10.1
MAM	14.4	14.4	0.6	**1.2**	2.1	**1.9**	4.0	**4.1**	10.8
JJA	23.4	23.5	0.6	**1.5**	3.0	**2.5**	5.7	**5.5**	15.3
SON	17.8	17.8	0.8	**1.2**	-1.6	**2.0**	-3.0	**4.7**	-8.0
January	8.7	9.0	1.4	**1.0**	0.8	**1.6**	1.6	**3.6**	4.3
February	9.2	9.3	1.2	**0.7**	4.4	**1.2**	8.6	**3.1**	22.9
March	10.9	10.9	1.0	**1.0**	-3.6	**1.6**	-7.0	**3.1**	-18.8
April	14.2	14.3	0.8	**1.2**	0.5	**1.9**	0.9	**3.7**	2.5
May	18.0	17.9	0.9	**1.3**	5.6	**2.2**	10.7	**5.0**	28.7
June	21.8	21.9	1.1	**1.5**	4.0	**2.5**	7.7	**5.5**	20.7
July	24.1	23.9	0.8	**1.5**	-0.4	**2.4**	-0.7	**5.4**	-1.9
August	24.4	24.4	0.8	**1.6**	-0.8	**2.7**	-1.6	**6.0**	-4.3
September	21.7	21.6	0.8	**1.2**	1.2	**2.1**	2.3	**5.1**	6.1
October	17.8	17.8	1.1	**1.3**	2.0	**2.1**	3.8	**4.9**	10.2
November	14.0	13.8	1.1	**0.9**	0.3	**1.5**	0.6	**3.5**	1.5
December	10.4	10.5	1.3	**1.2**	-2.5	**1.9**	-4.8	**3.5**	-12.9

For each month, the model computes potential evapotranspiration (PET) as a function of temperature. The portion SRC x P is distinguished from P as fast surface runoff, and the potential evapotranspiration is compared to P-(SRC x P). If this quantity is not sufficient to fulfill potential evapotranspiration, then water is drawn from the soil moisture of the previous month, and the moisture of the current month is decreased. If adequate water exists in soil storage to exceed the maximum holding capacity (SMAX), the surplus water is diverted to the river by the parameter SSRC. The remaining part is routed to the groundwater storage. The

Table 5. Generated Changes in Precipitation under the IPCC B2-MES Scenario.

Period	Baseline			2030		2050		2100	
	Observed	Modeled							
	Mean	Mean	Std.	Change	Ch. in Var.	Change	Ch. in Var.	Change	Ch. in Var.
	1	2	3	4	5	6	7	8	9
	mm/day	mm/day	mm/day	%	%	%	%	%	%
Annual	1.7	1.7	0.2	**-5.0**	5.6	**-8.0**	8.7	**-15.4**	16.2
DJF	3.3	3.1	0.7	**-2.7**	-2.6	**-4.7**	-4.0	**-10.2**	-7.5
MAM	1.7	1.6	0.4	**-5.1**	-1.9	**-7.9**	-3.0	**-14.4**	-5.6
JJA	0.3	0.3	0.1	**-26.1**	-5.5	**-36.8**	-8.5	**-59.9**	-15.9
SON	1.5	1.5	0.4	**-9.0**	-1.6	**-14.5**	-2.5	**-28.1**	-4.6
January	3.2	3.2	1.1	**-3.3**	8.9	**-5.5**	13.8	**-11.6**	25.8
February	2.9	2.7	1.1	**-0.7**	-14.2	**-2.6**	-22.0	**-7.9**	-41.1
March	2.4	2.2	0.9	**-0.2**	-3.2	**-0.1**	-4.9	**-0.6**	-9.2
April	1.5	1.5	0.5	**-5.9**	13.6	**-9.3**	21.1	**-16.2**	39.5
May	1.0	1.0	0.4	**-12.4**	-10.0	**-18.7**	-15.6	**-31.6**	-29.2
June	0.5	0.5	0.3	**-24.9**	-0.6	**-35.9**	-1.0	**-59.3**	-1.8
July	0.3	0.3	0.2	**-35.2**	-9.3	**-47.6**	-14.5	**-73.0**	-27.0
August	0.2	0.2	0.1	**-13.5**	-16.1	**-20.4**	-25.1	**-37.2**	-46.8
September	0.4	0.4	0.3	**-9.9**	-6.8	**-15.7**	-10.6	**-30.1**	-19.8
October	1.3	1.3	0.8	**-17.1**	-10.5	**-26.5**	-16.3	**-48.5**	-30.4
November	2.9	2.8	1.0	**-6.2**	1.2	**-10.5**	1.9	**-21.6**	3.5
December	3.8	3.5	1.2	**-4.4**	3.2	**-6.5**	5.0	**-12.1**	9.3

Table 6. Generated Changes in Precipitation under the IPCC A2-ASF Scenario.

Period	Baseline			2030		2050		2100	
	Observed	Modeled							
	Mean	Mean	Std.	Change	Ch. in Var.	Change	Ch. in Var.	Change	Ch. in Var.
	1	2	3	4	5	6	7	8	9
	mm/day	mm/day	mm/day	%	%	%	%	%	%
Annual	1.7	1.7	0.2	**-5.8**	4.4	**-10.2**	8.5	**-23.8**	22.7
DJF	3.3	3.1	0.7	**-5.6**	-2.0	**-9.2**	-3.9	**-19.0**	-10.5
MAM	1.7	1.6	0.4	**-7.4**	-1.5	**-11.5**	-2.9	**-21.9**	-7.8
JJA	0.3	0.3	0.1	**-15.5**	-4.3	**-26.4**	-8.3	**-66.3**	-22.3
SON	1.5	1.5	0.4	**-4.8**	-1.3	**-11.9**	-2.4	**-39.6**	-6.5
January	3.2	3.2	1.1	**-7.8**	7.0	**-11.9**	13.5	**-22.0**	36.1
February	2.9	2.7	1.1	**-1.2**	-11.2	**-4.5**	-21.5	**-16.3**	-57.6
March	2.4	2.2	0.9	**-9.9**	-2.5	**-11.6**	-4.8	**-8.4**	-12.8
April	1.5	1.5	0.5	**0.3**	10.7	**-3.1**	20.6	**-17.4**	55.2
May	1.0	1.0	0.4	**0.0**	-7.9	**-5.9**	-15.3	**-32.0**	-40.8
June	0.5	0.5	0.3	**-1.1**	-0.5	**-10.4**	-1.0	**-57.5**	-2.6
July	0.3	0.3	0.2	**-3.7**	-7.3	**-11.5**	-14.1	**-59.7**	-37.8
August	0.2	0.2	0.1	**-19.2**	-12.7	**-29.5**	-24.5	**-56.8**	-65.5
September	0.4	0.4	0.3	**-6.9**	-5.4	**-14.5**	-10.3	**-42.9**	-27.7
October	1.3	1.3	0.8	**-1.8**	-8.2	**-11.7**	-15.9	**-58.1**	-42.6
November	2.9	2.8	1.0	**-6.1**	1.0	**-12.6**	1.8	**-34.5**	4.9
December	3.8	3.5	1.2	**-7.2**	2.5	**-10.6**	4.9	**-19.3**	13.0

groundwater portion of the runoff is fed by groundwater storage of the previous month, using GWRC. Then, the surface runoff of the i^{th} month is computed as follows:

$$Q_i = SRC.P_i + SSRC.SSW_i + GWRC.GW_{i-1} \quad (1)$$

where, SRC is the surface runoff coefficient; Pi, precipitation in i^{th} month (mm); SSRC, subsurface runoff coefficient; SSWi, exceeded part of subsurface storage in i^{th} month (mm); GWRC, groundwater runoff coefficient; and GW_{i-1}, groundwater storage in i^{th} month (mm). The calibration of the model is based on the correlation between observed and modeled runoff values. The mean values of the modeled runoff series are also considered to test model fitness. The verified model parameters are used in the climate change scenarios for the years 2030, 2050 and 2100. As the runoff in the two basins are extensively controlled by several large and small dams for both hydropower and irrigation water supply purposes, there are only a few flow stations which are free of the effects of flow regulations. Thus, only the EIE509 (902 km^2) on Medar tributary of Gediz and EIE701 (948 km^2) on Cine tributary of Buyuk Menderes are used as the representative stations for model applications.

For simulation of EIE509 flows, precipitation and temperature records of Akhisar meteorological station in the Gediz Basin are used, while the records of Yatagan meteorological station are used for station EIE701 in the Buyuk Menderes Basin. The calibration of EIE509 and EIE701 flows is carried out with the observed runoff series of 1962-1979 and 1990-1995, respectively.The verification of the calibrated parameters is realized for the periods 1980-1996 and 1996-2000, respectively for the two stations.

As an example, Figure 3 shows the verification of both the observed and the modeled runoff for EIE509. Table 7 gives the calibration and verification criteria for both stations.

Table 7. Calibration and verification criteria for EIE509 station.

EIE509	Calibration		Verification	
	Model	Observed	Model	Observed
Mean	4.0 mm/month	4.1 mm/month	2.2 mm/month	2.5 mm/month
Correlation	0.76		0.78	

EIE701	Calibration		Verification	
	Model	Observed	Model	Observed
Mean	2.3 mm/month	2.6 mm/month	6.1 mm/month	5.4 mm/month
Correlation	0.78		0.80	

In the next step, a sensitivity analysis is realized by running the water budget model under the climate change scenarios to determine the variations in runoff due to predicted changes in precipitation and temperature. This study is carried out only for the station EIE509 in the Gediz Basin since it has a sufficiently long data records. Table 8 presents the results of this study as changes in runoff versus the hypothetical changes in precipitation and temperature. Basically, it is determined that any decrease in the basin runoff is sensitive to (a) increasing temperature in the order of 11% - 20%; (b) decreasing precipitation, in the order of 21% - 38%; and (c) both cases in the order of 29% - 52%.

In the last step of the modeling study, the water budget model is operated under the scenarios (IPCC SRES A2 and B2) of 2030, 2050 and 2100 climate conditions. The changes in runoff caused by decreases in precipitation and increases in temperature under the climate change scenarios B2 and A2 are presented in Table 9. Simulation results of the water budget model based on the prescribed climate change scenarios show that nearly 20% of the surface waters will be reduced by the year of 2030. By the years 2050 and 2100, this amount will rise to nearly 35% and more than 50%, respectively. The decreasing surface water potential of the basins will cause serious water stress problems among water users, mainly being agricultural, domestic and industrial water users.

Expected changes in water demand of crops specific for the region studied are also evaluated with respect to the climate change scenarios of **B2** and **A2.** Monthly potential evapotranspiration (**PET**) values of the selected crops are computed, using the Blaney-Criddle formula, which is the common method employed by the State Hydraulic Works (**DSI**) of Turkey in irrigation planning. According to the climate change scenarios of B2 and A2, the PET and crop water demands increase dramatically for the year 2100. Although the increases in PET are approximately 10%, 15% and 30% for the years 2030, 2050 and 2100, respectively, changes in water demand are higher than those in PET due to decreases in estimated rainfall, namely, the effective rainfall in the climate change scenarios (Table 10). Thus, while the crops demand more water than usual, the climate-induced reduction in rainfall values creates an additional impact so that the crop water demand increases dramatically.

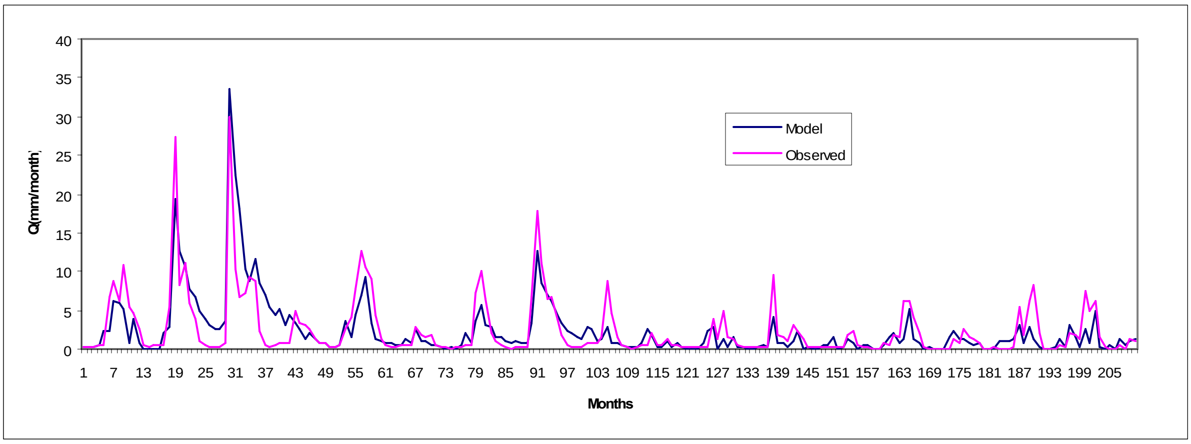

Figure 3. Observed and modeled runoff series of EIE509 in Gediz Basin (for 1980-1996 verification periods).

Table 8. The runoff variations versus the change in precipitation and temperature.

∂Q (%)		**∂P**				
		-10%	**-5%**	**0%**	**+5%**	**+10%**
∂t	**+2**	**-52**	**-37**	**-20**	-1	22
	+1	**-46**	**-29**	**-11**	11	36
	0	**-38**	**-21**	**0**	24	52
	-1	-31	-12	12	37	70
	-2	-23	-1	23	54	88

Table 9. The runoff changes under the climate conditions in 2030, 2050 and 2100 in Gediz and Buyuk Menderes River Basins.

	2030		2050		2100	
	B2	**A2**	**B2**	**A2**	**B2**	**A2**
EIE509 Gediz Basin	-%23	-%32	-%35	-%48	-%58	-%71
EIE701 B. Menderes Basin	-%10	-%21	-%20	-%38	-%45	-%71

CONCLUSION

In the presented study, the trend analyses on the runoff series in the Gediz and Buyuk Menderes Basins have revealed significant decreases over the entire period of runoff records between the years 1960 and 2000. Consequently, it may be stated that the effects of an expected climate change at regional scale in each basin would be to enhance the already existing water scarcity and water allocation problems. This, in turn, will worsen the current conflicts among water users, which have already started due to the high anthropogenic activities in both basins.

The future projections of the climate considering the different emission scenarios over the basins are also evaluated by GCMs. According to the results of B2-MESSAGE and A2-ASF, monthly temperatures increase to indicate that warmer winters are expected, while the summers get hotter. Although there are decreases in precipitation in all months regarding

Table 10. The average percentage change (increase) in potential evapotranspiration (PET) and crop water demand at selected meteorological stations in the region studied.

	2030				2050				2100			
	B2		**A2**		**B2**		**A2**		**B2**		**A2**	
GEDIZ	PET	Demand	PET	Demand	PET	Demand	PET	Demand	PET	Demand	PET	Demand
Menemen	12%	**13%**	10%	**11%**	16%	**20%**	17%	**19%**	27%	**36%**	36%	**47%**
Manisa	10%	**14%**	9%	**11%**	15%	**20%**	15%	**19%**	26%	**37%**	35%	**48%**
B.MENDERES												
Denizli	11%	**16%**	8%	**12%**	15%	**23%**	16%	**21%**	26%	**42%**	35%	**54%**
Nazilli	10%	**12%**	9%	**10%**	14%	**18%**	15%	**18%**	24%	**33%**	33%	**44%**

The model outcomes, the sharp decreases in spring and autumn are significantly important, because the summer seasons in the region are already dry. Simulation results of the water budget model have shown that the surface water potential of the test basins will decrease to cause serious water stress problems among water users. Furthermore, the increasing potential crop evapotranspiration will increase the irrigation water demand enormously.

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EFFECTS OF CLIMATE CHANGE AND ARIDITY ON ERGENE RIVER BASIN WATER PRODUCTIVITY

M. Dogan Kantarci

Istanbul University, Faculty of Forestry,Department of Soil Science and Ecology,
Bahcekoy-Istanbul-Turkey, mdkant@istanbul.edu.tr

ABSTRACT

The annual mean temperature in the temperate zones in Northern Hemisphere has increased by 1.4°C due to the changes in climate and it is expected that this increase will reach 2.5°C in the near future. At present, the mean annual temperature increase of 1.4°C leads to a net increase of around 2.0-2.5°C during the hot months of summer; resulting in increased evaporation from the water and soil surfaces while amplifying the transpiration from the plant leaves. Atmospheric CO_2 has reached 376 ppm as of year 2000 leading to a green-house effect and melt-down of glaciers, increased frequency and magnitude of hurricanes in oceans. Meanwhile, high mountains in Turkey also lost glaciers, large lakes such as Lake Tuz and Lake Burdur shrank, and shallow lakes such as Lake Akşehir and Lake Eber vanished. Increased evapo-transpiration could further expand the impact of the increase in temperatures by leading to escalation of summer aridity, potential harms on forests and agricultural lands, detrimental effects on fruit trees and vineyards, and amplified need for irrigation.

Ergene River basin, which is the major river basin in the central plains of Thrace region of Turkey, occupies 1 453 739 hectares. Agricultural land of this basin covers 73.4% and is a low-altitude land (<300m). Mountainous area, which provides water for irrigation reaches ~1000m and together with the forests, covers 19.3% of land. Currently, irrigated agriculture is performed on 123 827.86 hectares and this has been projected to be increased by another 257 493 hectares. The required water for irrigation of this land is 988 780 000 m^3 and will reach 1 914 590 000 m^3 by the projected increase in irrigated agricultural land. Together with the water required for drinking and house-hold use, total amount of water resources should reach 2 149 600 000 m^3 in near future.

Lüleburgaz Meteorological Station is located in the heart of Ergene River Basin and represents the most arid site. The analysis of the meteorological data from 1993 to 2005 has shown that the mean increase in temperature over the last 12 years was 1.2°C compared to the means between 1929 and 1970. Meanwhile, the temperature increase during the same period in time in other urban centers in the basin such as Edirne was +0.3°C, in Kırklareli +0.2°C, in Çorlu +0.4°C, and in Tekirdağ +0.4°C. Annual precipitation changes by ±5%. Taken together, water production in Ergene Basin decreased by 765 million m^3 between 1993 and 2005 compared to 1929-1970 and annual water deficit reached 798 million m^3. The majority of deficit in water is observed in and around agricultural lands (726 million m^3). These data suggest that the Ergene Basin is going through a very severe aridity and the model represented by Ergene Basin in this study demonstrates the dangerous transition of low agricultural lands to arid areas as a result of climate changes.

INTRODUCTION

The climate system of the earth, globally and locally, obviously has been changed from pre-industrial period to present. Some of the changes are due to natural phenomena and some due to human activities where the vital role has been played by the emission of so called "green house gasses". Especially, increase in atmospheric CO_2 has resulted in green house effect and global warming. The consequent increase in temperatures has also led to a net deficit in water saturation in atmosphere, which has caused excessive transpiration from plant, soil and water surfaces (Potential Evapo-Transpiration; PET). Land ecosystems require water to match increased transpiration to prevent aridity. Therefore, the chain reaction of CO_2-Warming-Evapo-Transpiration forms the basis of destruction for fragile ecosystems and agricultural lands to become deserts [Kantarcı 2000, Kantarcı 2005(a) and (b), Tokgöz- Kantarcı 2001].

Meanwhile, due to the warming, glaciers melt, warm and cold currents of Atlantic Ocean (Gulf Stream, Labrador Stream, respectively) change, water efficiency of resources in land ecosystems decreases, agricultural lands become arid, and necessity for irrigation increases.

EFFECT OF CO_2 ON ATMOSPHERIC WARMING

The warming in atmosphere and green-house effect is due to the increase in several gases; namely, carbon dioxide (CO_2), sulphur dioxide (SO_2), methane (CH_4), nitric oxides (NO_x), ozone (O_3) and water vapor (H_2O).

CO_2 increase in atmosphere is estimated to be increased by 0.004-fold annually that corresponds to 1.5 ppm volumetric increase. Overall, atmospheric CO_2 reaching from 280 ppm to 360 ppm causes a 1.4°C increase in temperature. This is due to the reflective action of CO_2 and SO_2 on the light beams emitted from the ground at 1.10-1.63 µm wavelength back to the earth. Meanwhile, CH_4 reflects 0.70-0.85µm wavelength red and infrared beams; however, CH_4 has a much shorter half-life (11 years) and has less atmospheric concentration (1.65 ppm) [Kantarcı 2005(a) and (b)].

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SIGNIFICANT EFFECTS OF ATMOSPHERIC WARMING IN TURKEY

Atmospheric warming has led to significant effects in Turkey especially after 1993 after which the changes were more notably measurable. The obvious results of the warming could be seen in glaciers in high mountains and lakes at low lands (especially in shallow lakes).

Glacier melt-down can be tracked by satellite images while people can directly observe these changes with their own eyes. Shallow lakes located in low altitudes either dried (e.g. Lake Akşehir, Lake Eber, and small lakes in closed Konya basin) or shrank (e.g. Lake Tuz, Lake Burdur).

Another important issue to consider within these lines is the increased frequency of heavy rains and their damaging effects in recent years. Deforestation in mountains and erosion also contribute to the destruction.

EFFECTS OF ATMOSPHERIC WARMING IN ERGENE RIVER BASIN (THRACE)

Characteristics of Ergene River Basin

Ergene River Basin occupies most of Thrace region in Turkey (63%) ranging between 0-1039 m in altitude. Agricultural land covers 73.4%, forests cover 19.3%, and grassland covers 7.3% of the basin. Most of the agricultural lands are located in low altitudes (<300 m) and occupy 1 067 475 hectares with a large portion of these lands (500 000 hectares) is available for irrigated agriculture. On the other hand, since there are no high mountains in the region, water resources are limited and only 123 827.86 hectares of the irrigable land can be utilized as such. This presents a demand for 988 780 000 m^3 of water. It is projected to increase the irrigated agriculture up to 257 493 hectares, which will increase the demand for irrigation water to 1 914 590 000 m^3. Taken together with the drinking and house-hold usage, water requirement for the basin will reach 2 149 600 000 m^3 in near future [Kantarcı 2005(a) and (b)].

Calculation of Warming in Ergene River Basin Based on the Measurements from 5 Meteorological Station

In this study, 5 meteorological stations in Ergene River Basin with records collected over long-term have been selected and temperatures[(*)] during 1929-1970, 1975-1992, 1993-2005 periods were compared (Table 1, Figure 1). The most arid area of the basin represented by Lüleburgaz station has shown an annual increase of 1.2ºC between 1993 and 2005 compared to 1929-1970. The same station's measurements showed a simultaneous decrease in precipitation of 29.3 mm (from 614.5 mm to 585.2 mm; -4.8%). Meanwhile, other stations showed much less pronounced changes in warming; Edirne +0.3ºC, Kırklareli +0.2ºC, Çorlu +0.4ºC, Tekirdağ +0.4ºC (Table 1, Figure 1). Precipitation changes for these 4 stations were recorded as +0.8% for Edirne, -6.3% for Kırklareli, +1.6% for Çorlu, and +5.0% for Tekirdağ (Table 1).

Method of Calculating the Impact of Warming on Water Balance

In order to calculate the impact of warming in Ergene River Basin on water balance, data on temperature and precipitation from 36 meteorological stations before 1970 were compared to the period between 1993 and 2005. The means were taken as 0.6ºC increase in temperature and 5.0% decrease in precipitation during 1993-2005.

Water balance was separately calculated for low lands (<300 m) and mountainous ranges (mean altitude 800 m). Agricultural lands are abundant in low lands and require water for irrigation while mountains are rich with forests and serve as the resources for water.

Another consideration in water balance calculation was the capillary water retention of soil (available water capacity of soil = AWC). This index was calculated as 210 mm/1m^3 in 1 m^2 area at 1 m depth in loamy soil without rocks. In order to measure the water deficit in agriculture land, soil depth has been taken as 0.5 m (to represent the root development depth of shallow rooted agricultural plants) and AWC was taken as 105 mm/0.5m^3. Forest, grassland, and agricultural lands have been separately measured.

[(*)] Raw data were taken from "TSMS 1974 and 2005" references. All analysis and evaluations only belong to the author.

Table 1. Trends of annual mean "temperature" measurements during 1929-70 and 1975-92 and 1993-2005 periods, according to five meteorological stations in thrace

MONTHS	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	ANNUAL
							MEAN TEMPERATURE (ºC)						
EDİRNE													
1929 - 1970	1.9	3.8	6.9	12.6	17.9	21.9	24.6	24.1	19.6	14.3	9.4	4.5	13.5
1975 - 2005	2.8	4.2	7.6	12.4	17.9	22.3	24.5	23.9	19.8	14.1	8.5	4.2	13.5
1975 - 1992 (18 YEARS)	2.6	4.0	7.7	12.7	17.5	21.9	24.0	23.3	19.7	13.8	8.4	4.2	13.3
1993 - 2005 (13 YEARS)	3.0	4.4	7.5	12.8	18.5	22.9	25.3	24.6	19.9	14.4	8.6	4.2	13.8
(1929 - 1970) - (1993- 2005)	+ 1.1	+ 0.6	+ 0.6	+ 0.2	+ 0.6	+ 0.1	+ 0.7	+ 0.5	+ 0.3	+ 0.1	- 0.8	- 0.3	+ 0.3
RATIO %	+ 57.9	+ 16	+ 8.7	+ 1.6	+ 3.3	+ 4.6	+ 2.8	+ 2.1	+ 1.5	+ 0.0	- 8.5	- 6.7	+ 2.2
(1975-1992) - (1993-2005)	+ 0.4	+ 0.4	- 0.2	+ 0.1	+ 1.0	+ 1.0	+ 1.3	+ 1.3	+ 0.2	+ 0.6	+ 0.2	-	+ 0.5
RATIO %	+ 0.3												+ 3.7
KIRKLARELİ													
1929 - 1970	1.7	4.2	6.2	11.9	17.1	21.5	23.6	22.9	19.1	13.9	10.2	5.6	13.2
1975 - 2005	3.2	3.7	6.8	11.9	17.1	21.4	23.8	23.1	19.1	13.8	8.5	4.7	13.1
1975 - 1992 (18 YEARS)	2.9	3.5	6.9	11.8	16.5	21.1	23.2	22.5	19.0	13.6	8.5	4.7	12.9
1993 - 2005 (13 YEARS)	3.4	4.0	6.7	12.0	17.7	22.0	24.6	23.8	19.2	14.2	8.7	4.8	13.4
(1929-1970) - (1993-2005)	+ 1.7	- 0.2	+ 0.5	+ 0.1	+ 0.6	+ 0.5	+ 1.0	+ 0.9	+ 0.1	+ 0.3	- 1.5	- 0.8	+ 0.2
RATIO %	+100.0	- 4.8	+ 8.1	+ 0.0	+ 3.5	+ 2.3	+ 4.2	+ 3.9	+ 0.0	+ 2.2	-14.7	- 14.3	+ 1.5
(1975-1992) - (1993-2005)	+ 0.5	+ 0.5	- 0.2	+ 0.2	+ 1.2	+ 0.9	+ 1.4	+ 1.3	+ 0.2	+ 0.6	+ 0.2	+ 0.1	+ 0.5
RATIO %	+ 17.2												+ 3.9
LÜLEBURGAZ													
1929 – 1970	2.9	4.0	6.2	11.6	16.8	20.8	23.4	23.2	18.8	14.0	9.7	5.5	13.1
1975 - 2005	3.5	4.2	7.0	11.4	16.8	21.6	23.7	23.0	19.1	14.5	8.7	5.1	13.2
1975 - 1992 (18 YEARS)	3.0	3.7	6.6	10.7	15.8	20.5	22.3	21.7	18.3	13.3	8.4	4.8	12.4
1993 - 2005 (13 YEARS)	4.2	4.8	7.5	12.5	18.3	23.2	25.7	24.8	20.3	15.1	9.2	5.6	14.3
(1929- 1970) - (1993-2005)	+ 1.3	+ 0.3	+ 1.3	+ 0.3	+ 1.5	+ 2.5	+ 2.3	+ 1.6	+ 1.5	+ 1.1	- 0.5	+ 0.1	+ 1.2
RATIO %	+ 44.8	+ 20.0	+ 21.0	+ 7.7	+ 8.9	+ 12.0	+ 9.8	+ 6.9	+ 8.0	+ 7.9	- 5.1	+ 1.8	+ 9.2
(1975-92) - (1993-2005)	+ 1.2	+ 1.1	+ 0.9	+ 1.8	+ 2.5	+ 2.7	+ 3.4	+ 3.1	+ 2.0	+ 1.8	+ 0.8	+ 0.8	+ 1.9
RATIO %	+ 40.0												+ 15.3
ÇORLU													
1929 - 1970	2.8	3.9	5.8	11.0	16.0	19.9	22.4	22.2	18.4	14.0	10.4	5.7	12.2
1975 - 2005	3.6	3.8	6.4	11.2	15.9	20.5	22.6	22.0	18.6	14.0	9.0	5.2	12.8
1975 - 1992 (18 YEARS)	3.4	3.6	6.4	11.2	15.5	20.3	22.0	21.5	18.4	13.7	8.9	5.2	12.5
1993 - 2005 (13 YEARS)	3.8	4.1	6.5	11.2	16.4	20.9	23.4	22.7	18.9	14.4	9.1	5.3	13.1
(1929-1970) - (1993 - 2005)	+ 1.0	+ 0.2	+ 0.7	+ 0.2	+ 0.4	+ 1.0	+ 1.0	+ 0.5	+ 0.5	+ 0.4	- 1.3	- 0.4	+ 0.4
RATIO %	+ 35.7	+ 5.1	+ 12.0	+ 1.8	+ 2.5	+ 5.0	+ 4.5	+ 2.2	+ 2.7	+ 2.9	- 12.5	- 7.0	+ 3.1
(1975-1992) - (1993-2005)	+ 0.4	+ 0.5	+ 0.1	-	+ 0.9	+ 0.6	+ 1.4	+ 1.2	+ 0.5	+ 0.7	+ 0.2	+ 0.1	+ 0.6
RATIO %	+ 11.8												+ 4.8
TEKİRDAĞ													
1929 - 1970	4.3	5.2	6.7	11.5	16.6	20.9	23.4	23.5	19.7	15.3	11.4	7.3	13.8
1975 - 2005	5.0	5.0	7.3	11.7	16.5	21.1	23.6	23.3	19.8	15.2	10.4	6.8	13.8
1975 - 1992 (18 YEARS)	4.8	4.8	7.2	11.7	16.2	20.8	23.0	22.8	19.6	14.9	10.3	6.8	13.6
1993 - 2005 (13 YEARS)	5.2	5.2	7.4	11.8	17.0	21.5	24.4	24.1	20.2	15.7	10.5	6.9	14.2
(1929 - 70) - (1993 - 2005)	+ 0.9	+ 0.0	+ 0.7	+ 0.3	+ 0.4	+ 0.6	+ 1.0	+ 0.6	+ 0.5	+ 0.4	- 0.9	- 0.4	+ 0.4
RATIO %	+ 20.9	0.0	+ 10.4	+ 12.6	+ 2.4	+ 2.9	+ 4.3	+ 2.5	+ 2.5	+ 2.6	- 7.9	- 5.5	+ 2.9
(1975- 1992) - (1993 - 2005)	+ 0.4	+ 0.4	+ 0.2	+ 0.1	+ 0.8	+ 0.7	+ 1.4	+ 1.3	+ 0.6	+ 0.8	+ 0.2	+ 0.1	+ 0.6
RATIO %	+ 8.3												+4.4

Table 2. Trends of annual mean "precipitation" during 1929-70 and 1975-92 and 1993-2005 periods according to five meteorological stations in thrace

MONTHS	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	ANNUAL
MEAN PRECIPITATION (mm)													
EDİRNE													
1929 - 1970	65.1	50.7	45.6	47.8	47.0	49.5	32.3	22.0	31.0	55.3	72.4	80.6	599.3
1975 - 2005	51.5	45.1	48.0	48.1	55.9	38.4	31.1	28.0	34.0	50.0	74.1	67.9	572.1
1975 - 1992	49.8	43.1	47.4	52.6	53.0	42.9	23.7	25.9	28.5	49.9	72.7	59.8	549.3
1993 - 2005	53.8	47.9	48.8	41.9	59.9	32.1	41.4	30.9	41.7	50.3	76.1	79.0	603.8
(1929-70) - (1993-2005)	-11.3	- 2.8	+ 3.2	-5.9	+ 12.9	- 17.4	+ 9.1	+ 8.9	+ 10.7	- 5.0	+ 3.7	- 1.6	+ 4.5
RATIO %	- 17.4	- 5.5	+ 7.0	- 12.3	+ 27	- 35.1	+ 28.2	+ 40.4	+ 34.5	- 9.0	+ 5.1	- 2.0	+ 0.0
(1975-92) - (1993-2005)	+ 4.0	+ 4.8	+ 1.4	- 10.2	+ 6.9	- 10.8	+ 17.7	+ 5.0	+ 13.2	+ 0.4	+ 3.4	+ 15.2	+ 54.5
RATIO %	+ 7.4	+ 11.1	+ 3.0	- 19.4	+ 13.0	- 25.2	+ 74.7	+ 19.3	+ 46.3	+ 0.0	+ 4.7	+ 32.1	+ 9.9
KIRKLARELİ													
1929 - 1970	68.6	53.0	47.5	41.6	48.7	49.1	25.8	21.2	25.4	45.1	69.2	80.5	576.8
1975 - 2005	51.5	38.8	42.1	44.9	50.5	50.2	25.7	23.1	24.8	47.8	73.4	65.5	538.4
1975 - 1992	51.2	36.5	42.1	49.4	49.0	55.3	22.4	21.6	16.3	48.5	77.2	67.5	537
1993 - 2005	52.0	42.0	42.1	38.8	52.5	43.2	30.3	25.3	36.5	46.9	68.1	62.7	540.4
(1929-70) - (1993-2005)	-16.6	- 11.0	- 5.4	-2.8	+3.8	- 5.9	+ 4.5	+ 4.1	+ 11.1	+ 1.8	- 1.1	- 17.8	- 36.4
RATIO %	- 24.2	- 20.7	- 11.4	- 6.7	+ 7.8	- 12.0	+ 17.4	+ 19.3	+ 43.7	+ 4.0	- 1.6	- 22.1	- 6.3
(1975-92) - (1993-2005)	+ 8.0	+ 5.5	0.0	- 10.6	+ 3.5	- 2.1	+ 7.9	+ 3.7	+ 20.2	- 1.6	- 9.1	- 4.8	+ 3.4
RATIO %													+ 0.06
LÜLEBURGAZ													
1929 - 1970	74.7	59.4	52.1	42.1	45.7	52.3	25.3	16.5	32.1	50.9	77.5	85.9	614.5
1975 - 2005	61.0	42.5	49.6	47.5	44.8	39.9	32.4	15.1	25.8	58.2	77.3	78.6	572.7
1975 - 1992	63.7	35.7	47.3	54.2	41.2	45.4	30.7	11.3	17.2	60.3	88.8	67.7	563.5
1993 - 2005	57.2	51.8	52.7	38.3	49.7	32.3	34.8	20.4	37.6	55.2	61.4	93.8	585.2
(1929-70) - (1993-2005)	- 17.5	- 7.6	+ 0.6	- 3.8	- 4.0	- 20.0	+ 9.5	+ 3.9	+ 5.5	+ 4.3	- 16.1	+ 7.9	- 29.3
RATIO %	- 23.0	-13.0	+ 1.0	- 9.0	- 9.0	- 38.0	+ 4.0	+ 24.0	+17.0	+ 8.0	- 21.0	+ 9.0	- 4.8
(1975-92) - (1993-2005)	- 6.5	+ 16.1	+ 5.4	- 15.9	+ 8.5	- 13.1	+ 4.1	+ 9.1	+ 10.4	- 5.1	- 27.4	+ 26.1	+ 21.7
ORAN %													+3.8
ÇORLU													
1929 - 1970	72.6	57.7	56	43.1	35.7	37.5	19.2	9.2	29.8	52.2	82.6	95.8	568.6
1975 - 2005	59.8	51	52.4	46.7	41.3	36.8	26.8	17.8	29.8	58.9	74.5	84.5	566.3
1975 - 1992	63.8	37.0	46.3	50.1	44.1	41.7	28.2	16.5	19.7	54	77.4	73.2	558.2
1993 - 2005	54.2	69.2	60.5	42.2	37.6	30.4	25.1	19.4	43	65.3	70.7	91.7	578
(1929-70) - (1993-2005)	- 18.4	+ 11.5	+ 4.5	- 0.9	+ 1.9	- 7.1	+ 5.9	+ 10.2	+ 13.2	+ 13.1	- 11.9	- 4.1	+ 9.4
RATIO %	-25.0	+ 20.0	+ 8.0	- 2.0	+ 5.0	- 19.0	+ 30.7	+ 11.0	+ 44.3	+ 25.0	- 14.4	- 4.0	+ 1.6
(1975-92) - (1993-2005)	- 9.6	+ 32.2	+ 14.2	- 7.9	- 6.5	- 11.3	- 3.1	+ 2.9	+ 23.3	+ 11.3	- 6.7	+ 18.5	+ 19.8
RATIO %	- 15.0	+ 87.0	+ 30.7	- 15.6	- 14.7	- 27.1	- 11.0	+ 17.6	+ 118.3	+ 20.9	- 8.6	+ 25.3	+ 3.5
TEKİRDAĞ													
1929 - 1970	71.8	57.7	56	43.1	35.7	37.5	19.2	9.2	29.8	52.2	82.6	95.8	590.5
1975 - 2005	66.3	51	52.4	46.7	41.3	36.8	26.8	17.8	29.8	58.9	74.5	84.5	586.8
1975 - 1992	67.3	37.0	46.3	50.1	44.1	41.7	28.2	16.5	19.7	54	77.4	73.2	555.5
1993 - 2005	65.0	69.2	60.5	42.2	37.6	30.4	25.1	19.4	43	65.3	70.7	91.7	620.1
(1929-70) - (1993-2005)	- 6.8	+ 11.5	+ 4.5	- 0.9	+ 1.9	- 7.1	+ 5.9	+ 10.2	+ 13.2	+ 13.1	- 11.9	- 4.1	+ 20.6
RATIO %	- 10.0	+ 20.0	+ 8.0	- 2.0	+ 5.0	- 19.0	+ 30.7	+ 11.0	+ 44.3	+ 25.0	- 14.4	- 4.0	+ 5.0
(1975-92) - (1993-2005)	- 2.3	+ 32.2	+ 14.2	- 7.9	- 6.5	- 11.3	- 3.1	+ 2.9	+ 23.3	+ 11.3	- 6.7	+ 18.5	+ 64.6
RATIO %	- 3.4	+ 87.0	+ 30.7	- 15.6	- 14.7	- 27.1	- 11.0	+ 17.6	+ 118.3	+ 20.9	- 8.6	+ 25.3	+ 11.6

Table 3. Trends annual mean precipitation and mean temperature measurements in thrace based on the january, five summer months taken from five meteorological stations in 1929-70 and 1975-92 and 1993-2005 periods

	JANUARY			FIVE SUMMER MONTS			JULY			ANNUAL		
	PRECIP. mm	MEAN TEMP. C°	MEAN MAX. TEMP.	PRECIP. mm	MEAN TEMP. C°	MEAN MAX. TEMP C°	PRECIP mm	MEAN TEMP. C°	MEAN MAX. TEMP C°	PRECIP. mm	MEAN TEMP. C°	MEAN MAX. TEMP. C°
EDİRNE												
1929 -1 970	65.1	1.9	5.6	181.8	21.6	-	32.3	24.6	-	559.0	13.5	-
1975 - 2005	51.5	2.8	-			-	31.1	24.5	-	572.1	13.5	-
1975-1992 (18 YEARS)	49.8	2.6	-	174.0	21.3	-	23.7	24.0	-	549.3	13.3	-
1993-2005 (13 YEARS)	53.8	3.0	-	206.0	22.2	-	41.4	25.3	-	603.8	13.8	-
(1929-70) - (1993-2005)	-	+ 1.1	-	+ 24.2	+ 0.6	-	+ 9.1	+ 0.7	-	-	+ 0.3	-
RATIO %	-	+ 57.9	-	+ 13.3	+ 2.7	-	+ 28.2	+ 2.8	-	-		-
(1975-92) - (1993-2005)	+ 4.0	+ 0.4	-	+ 32.0	+ 0.9	-	+ 17.7	+ 1.3	-	+ 54.5	+ 0.5	-
RATIO %	+ 7.4	+ 15.3	-	+ 18.4	+ 4.2	-	+ 74.7		-	+ 9.9	-	-
KIRKLARELİ												
1929 - 1970	68.6	1.7	5.0	170.2	20.8	27.4	25.8	23.6	-	576.0	13.2	18.4
1975 - 2005	51.5	3.2	6.7			27.5	25.7	23.8	-	538.4	13.1	18.5
1975-1992 (18 YEARS)	51.2	2.9	6.5	164.6	20.5	27.0	22.4	23.2	-	537.0	12.9	18.2
1993-2005 (13 YEARS)	52.0	3.4	7.0	187.8	21.5	28.2	30.3	24.6	-	540.4	13.4	19.0
(1929-70) - (1993-2005)	-	+ 1.7	+ 2.0	+ 17.6	+ 0.7	+ 0.6	+ 4.5	+ 1.0	-	- 35.6	+ 0.2	+ 0.6
RATIO %	-	+ 100.0	+ 40.0	+ 10.3	+ 3.2	+ 2.2	+ 17.4	+ 4.2	-	- 6.2	+ 1.5	+ 3.3
(1975-92) - (1993-2005)	+ 0.8	+ 0.5	+ 0.5	+ 23.2	+ 1.0	+ 1.2	+ 7.9	+ 1.4	-	+ 3.4	+ 0.5	+ 0.8
RATIO %	-	+ 17.2	+ 7.7	+ 14.1	+ 4.9	+ 4.4	-	-	-	+ 0.06	+ 3.9	+ 4.4
LÜLEBURGAZ												
1929 - 1970	74.7	2.9	6.7	171.9	20.6	27.8	25.3	23.4	-	614.5	13.1	19.2
1975 - 2005	61.0	3.5	8.0	158.0	20.7	28.7	32.4	23.7	-	572.7	13.2	19.8
1975-1992 (18 YEARS)	63.7	3.0	7.6	145.8	19.7	27.5	30.7	22.3	-	563.5	12.5	19.1
1993-2005 (13 YEARS)	57.2	4.2	8.7	174.8	22.4	30.3	34.8	25.7	-	585.2	14.3	20.9
(1929-70) - (1993-2005)	- 13.7	+ 1.3	+ 2.0	+ 2.9	+ 1.8	+ 2.5	+ 9.5	+2.3	-	+ 29.3	+ 1.2	+ 1.7
RATIO %	- 18.3	+ 44.8	+ 29.8	+ 1.7	+ 8.7	+ 9.0		+ 9.8	-	+ 4.8	+ 9.2	+ 8.8
(1975-92) - (1993-2005)	- 6.5	+ 1.2	+ 1.1	+ 29.0	+ 2.7	+ 2.8	+ 4.1	+ 3.4	-	+ 21.7	+ 1.9	+ 1.8
RATIO %	- 15.5	+40.0	+ 14.4	+ 20.0	+ 13.7	+ 10.2	-	-	-	+ 3.8	+ 15.3	+ 9.4
ÇORLU												
1929 - 1970	72.6	2.8	-	143.5	19.8	-	15.4	22.4	-	568.6	12.7	-
1975 - 2005	59.8	3.6	-	161.8	19.9	-	27.9	22.6	-	566.3	8.0	-
1975-1992 (18 YEARS)	63.8	3.4	-	159.7	19.5	-	32.0	22.0	-	558.2	12.5	-
1993-2005 (13 YEARS)	54.2	3.8	-	165.0	20.5	-	22.1	23.4	-	578.0	13.1	-
(1929-70) - (1993-2005)	-	+ 1.0	-	+ 21.5	+ 0.7	-	+ 6.7	+ 1.0	-	+ 9.4	+ 0.4	-
RATIO %	-	+ 35.7	-	+ 15.0	+ 3.6	-	+ 43.5	+ 4.5	-	+ 1.6	+ 3.1	-
(1975-92) - (1993-2005)	- 9.6	+ 0.4	-	+ 5.3	+ 1.0	-	- 9.9	+ 1.4	-	+ 19.8	+ 0.6	-
RATIO %	+15.0	+11.8	-	+ 3.3	+ 5.1	-	- 30.5	-	-	+ 3.5	+ 4.8	-
TEKİRDAĞ												
1929 - 1970	71.8	4.3	-	131.4	20.8	-	19.2	23.4	-	590.5	13.8	-
1975 - 2005	66.3	5.0	-	152.5	20.7	-	26.8	23.6	-	586.8	13.8	-
1975-1992 (18 YEARS)	67.3	4.8	-	150.2	20.5	-	28.2	23.0	-	555.5	13.6	-
1993-2005 (13 YEARS)	65.0	5.2	-	155.5	21.4	-	25.1	24.4	-	620.1	14.2	-
(1929-70) - (1993-2005)	-	+ 0.9	-	+ 24.1	+ 0.6	-	+ 5.9	+ 1.0	-	+ 29.6	+ 0.4	-
RATIO %	-	+ 20.9	-	+ 18.3	+ 2.8	-	+ 30.7	+ 4.3	-	+ 5.0	+ 2.9	-
(1975-92) - (1993-2005)	- 2.3	+ 0.4	-	+ 5.3	+ 0.9	-	- 3.1	+ 1.4	-	+ 64.6	+ 0.6	-
RATIO %	- 3.4	+ 8.3	-	+ 3.5	+ 4.4	-	- 11.0	-	-	+ 11.6	+ 4.4	-

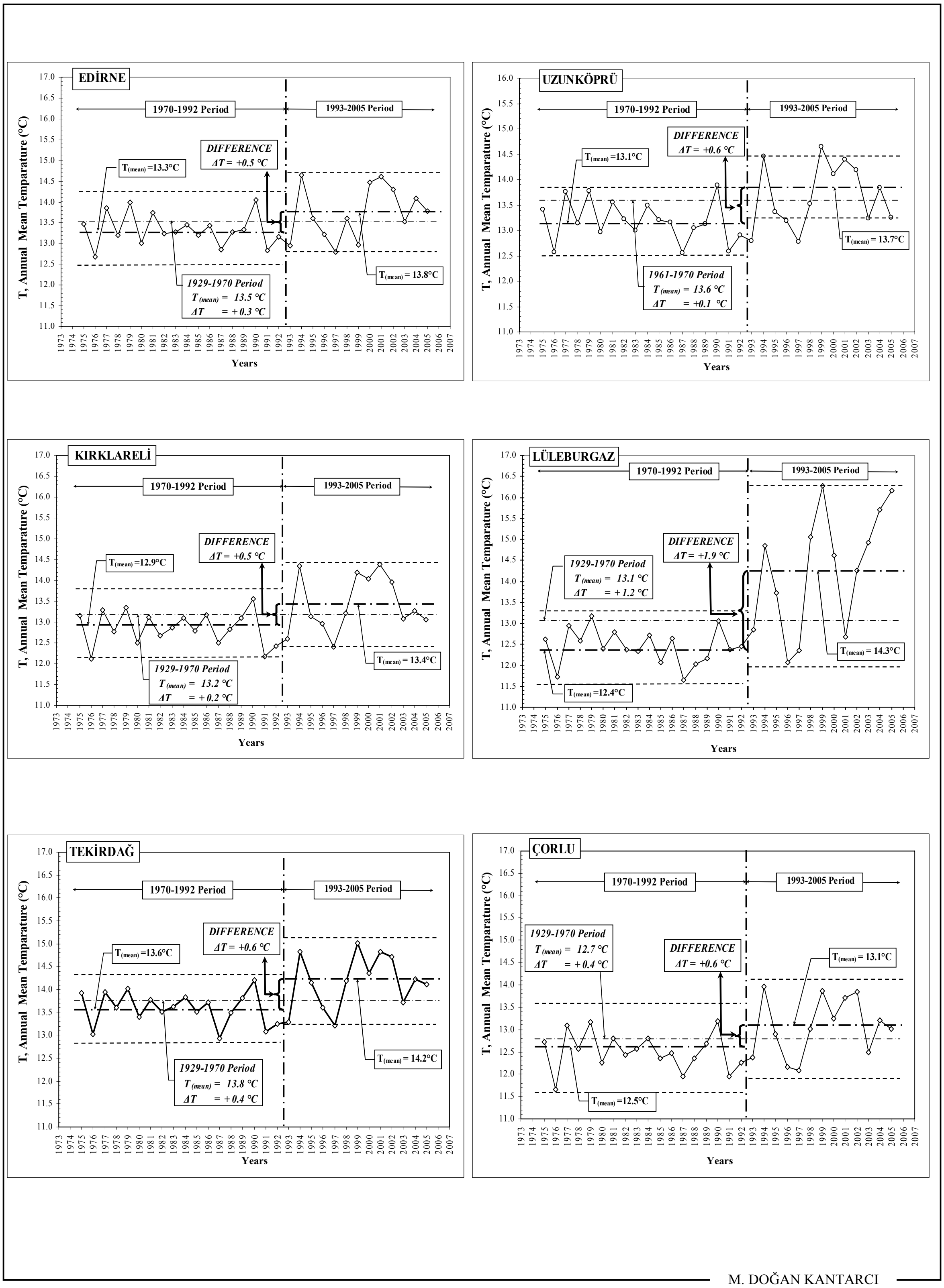

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Figure 1. Trends of the annual mean temperature measurements during the 1929-1970 and 1970 - 1992 and 1993-2005 periods according to six meteorological stations data in thrace

Results: Water Balance in Unit Area (1 m^2)

Potential Evapo-Transpiration (PET) is an important measure in calculating water balance. PET is solely dependent on temperature changes. In low altitudes (<300 m) in Ergene River Basin, PET value for 1929-1970 period was 603.5 mm/m^2 for 13.4ºC while in 1993-2005 period, it reached up to 677.5 mm/m^2 for 14.0ºC. The difference (+74.0 mm/m^2) represents an increase of 12.3%. In high altitudes, PET is calculated as 330.4 mm/m^2 during 1929-1970 for 11.0ºC and 406.7 mm/m^2 in 1993-2005 for 11.6ºC. The difference (+76.3 mm/m^2) represents and increase of 23% (Figure 2).

Water deficit is 123.7 mm/m^3 in low altitudes in Ergene Basin during 1929-1970 and raises to 191.7 mm/m^3 in 1993-2005. While there is no water deficit in high altitudes in both periods of time, excess water declined from 469.6 mm/m^3 (1929-1970) to 353.3 mm/m^3 (1993-2005) representing a net change of -116.3mm/m^3 (-24.8%). Real evapo-transpiration (RET) in high altitudes has increased from 330.4 mm/m^3 to 406.7 mm/m^3 (Figure 2). In low altitudes, excess water is 147.6 mm/m^3 in 1929-1970 and 110.3 mm/m^3 in 1993-2005. The difference is -37.3 mm/m^3 and represents a decrease of 25% (Figure 2).

In agricultural lands, water deficit is calculated 228.7 mm/0.5m^3 in 1929-1970 and 296.7 mm/0.5m^3 in 1993-2005. The difference is +68.0 mm/0.5m^3 and corresponds to an increase of 30% (Figure 3). Water deficit is calculated 46.5 mm / 0.5 m^3 in 1993-2005 period in agricultural lands in high altitudes.

CONCLUSIONS

Figure 4 represents the summary of over all findings in forest, grasslands, and agricultural lands:

1. There is not water deficit in forest areas.

2. In grasslands, water deficit per 1m - depth soil has increased from 131 million m^3/year to 203 million m^3/year with a net increase of 72 266 320 m^3/year (55%).

3. In agricultural lands, water deficit has increased from 1.320 billion m^3/year to 2.046 billion m^3/year representing a net increase of 725 883 000 m^3/year (55%).

4. Overall water deficit has increased from 1.452 billion m^3/year to 2.250 billion m^3/year (+798 149 320 m^3/year).

5. Excess water was 3.049 billion m^3/year in 1929-1970 and decreased to 2.284 billion m^3/year in 1993-2005. The difference is - 765 436 747 m^3/year and 25%.

6. In agricultural lands (for 0.5 m soil depth), water deficit was determined 2.441 billion m^3/year in 1929-1970 and 3.167 billion m^3/year in 1993-2005. The difference was calculated + 725 883 000 m^3/year (30%).

7. These data suggest that the Ergene Basin is going through a very severe aridity and the model represented by Ergene Basin in this study demonstrates the

dangerous transition of low agricultural lands to arid areas as a result of climate changes.

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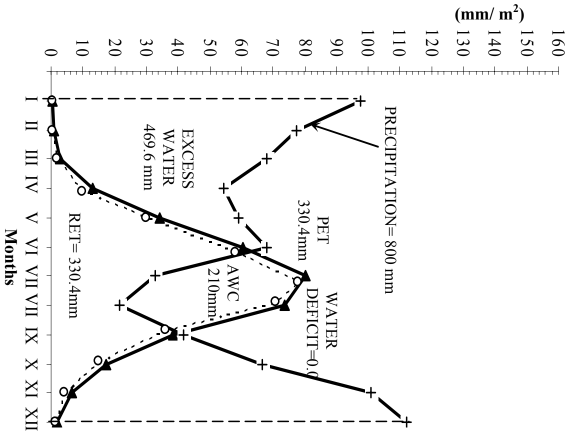
Figure 2. Water balances of the sub basin (< 300 m) and upper basin (300-1000 m) within the ergene basin / thrace between 1929-1970 and 1993-2005 (warming) periods. [Mean values were calculated according to temperature and precipitation data taken from 36 meteorological stations in 1929-70 period. As follows figures, some derived data were taken into consideration by +0.6ºC increase in temperature and -5.0% decrease in precipitation during the warming period (1993-2005) and AWC = 210 mm/ m^3, non-stony loamy soil].

WATER BALANCE OF THE UPPER BASIN DURING THE 1929-1970 PERIOD

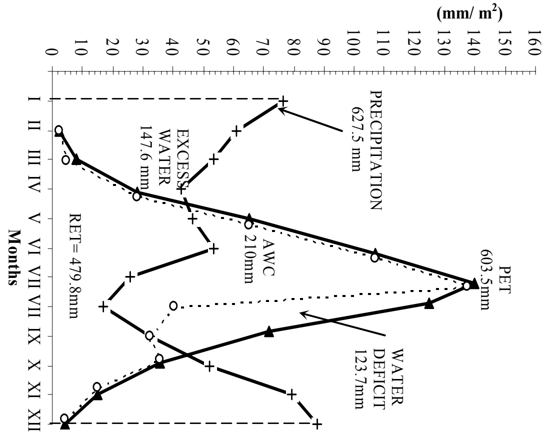
[Altitude= 300-1000 m (in field=800m), Temperature=11.0 ºC, Precipitation=800 mm]



PET mm	PRECIPI-TATION mm	RET mm	WATER DEFICIT mm	EXCESS WATER mm
0.4	97.6	0.4	-	97.2
0.8	77.6	0.8	-	76.8
3.0	68.0	3.0	-	65.0
13.3	54.4	13.3	-	41.1
34.4	59.2	34.4	-	24.8
60.5	68.0	60.5	-	7.5
80.0	32.8	80.0	-	-
73.8	21.6	73.8	-	-
38.5	41.6	38.5	-	-
17.3	66.4	17.3	-	-
6.6	100.8	6.6	-	47.0
1.8	112.0	1.8	-	110.2
Σ 330.4	**800.0**	**330.4**	-	**469.6**
AWC (in soil) = 210 mm / m^3				

WATER BALANCE OF THE SUB BASIN DURING THE 1929-1970 PERIOD

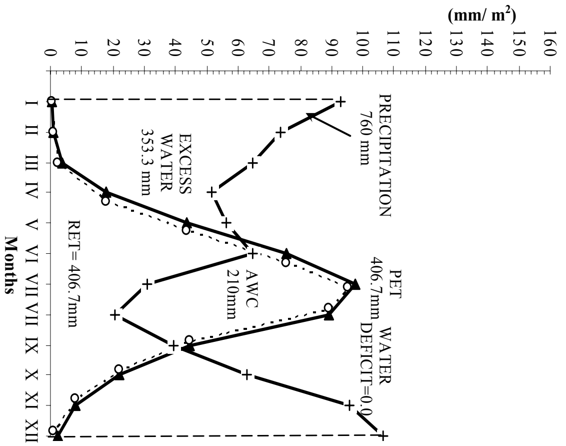
[Altitude < 300 m , Temperature = 13.4 ºC, Precipitation = 627.5 mm]



PET mm	PRECIPI-TATION mm	RET mm	WATER DEFICIT mm	EXCESS WATER mm
1.6	76.6	1.6	-	29.3
2.5	60.9	2.5	-	58.4
7.8	53.3	7.8	-	45.5
28.3	42.7	28.3	-	14.4
65.0	46.4	65.0	-	-
107.1	53.3	107.1	-	-
139.7	25.7	139.7	-	-
125.0	16.9	40.5	84.5	-
71.8	32.6	32.6	39.2	-
35.5	52.1	35.5	-	-
14.8	79.1	14.8	-	-
4.4	87.8	4.4	-	-
Σ 603.5	627.5	479.8	123.7	147.6
AWC (in soil) = 210 mm / m^3				

WATER BALANCE OF THE UPPER BASIN DURING THE 1993-2005 PERIOD

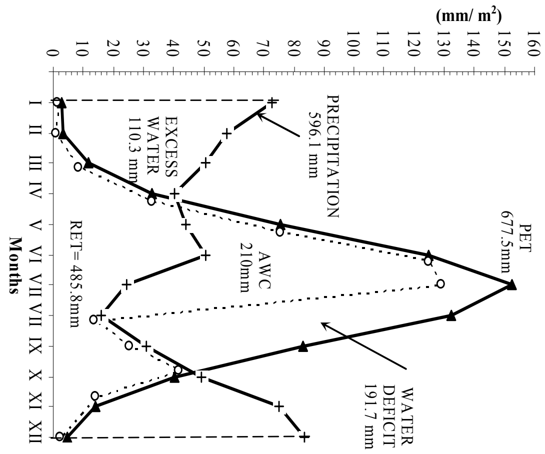
[Altitude=300-1000 m (in field=800m), Temperature = (+0.6ºC) 11.6ºC, Precipitation=760 mm]



PET mm	PRECIPI-TATION mm	RET mm	WATER DEFICIT mm	EXCESS WATER mm
0.5	92.7	0.5	-	92.2
1.0	73.7	1.0	-	72.7
3.8	64.6	3.8	-	60.8
17.8	51.7	17.8	-	33.9
43.7	56.2	43.7	-	12.5
75.6	64.6	75.6	-	0.0
97.8	31.2	97.8	-	0.0
89.2	20.5	89.2	-	0.0
44.7	39.5	44.7	-	0.0
22.1	63.1	22.1	-	0.0
8.2	95.8	8.2	-	0.0
2.3	106.4	2.3	-	81.2
Σ 406.7	**760.0**	**406.7**	-	**353.3**
AWC (in soil) = 210 mm / m^3				

WATER BALANCE OF THE SUB BASIN DURING THE 1993-2005 PERIOD

[Altitude < 300 m , Temperature = (+0.6ºC) 14.0 ºC, Precipitation = 596.1 mm]

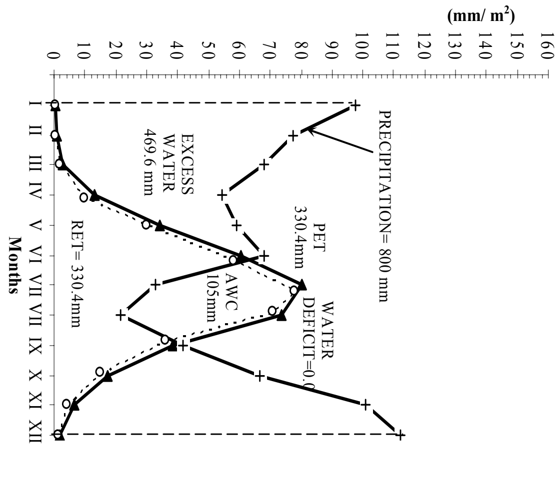


PET mm	PRECIPI-TATION mm	RET mm	WATER DEFICIT mm	EXCESS WATER mm
2.6	72.8	2.6	-	9.3
3.5	57.8	3.5	-	54.3
11.8	50.7	11.8	-	38.9
32.7	40.5	32.7	-	7.8
75.6	44.1	75.6	-	-
124.7	50.7	124.7	-	-
152.4	24.4	128.9	23.5	-
132.1	16.1	16.1	116.0	-
83.2	31.0	31.0	52.2	-
40.3	49.5	40.3	-	-
13.9	75.1	13.9	-	-
4.7	83.4	4.7	-	-
Σ 677.5	**596.1**	**485.8**	**191.7**	**110.3**
AWC (in soil) = 210 mm / m^3				

Figure 3. Water balance on the warming period (1929-70 and 1993-2005) in the agricultural lands in ergene basin/ thrace.
[Mean values were calculated according to temperature and precipitation data taken from 36 meteorological stations in 1929-70 period. As follows figures, some derived data were taken into consideration during 1993-2005 warming period by +0.6ºC increase in temperature and -5.0% decrease in precipitation and available water capacity AWC = 105 mm/ 0.5m^3 and non-stony loamy soil].

WATER BALANCE OF THE UPPER BASIN DURING THE 1929-1970 PERIOD

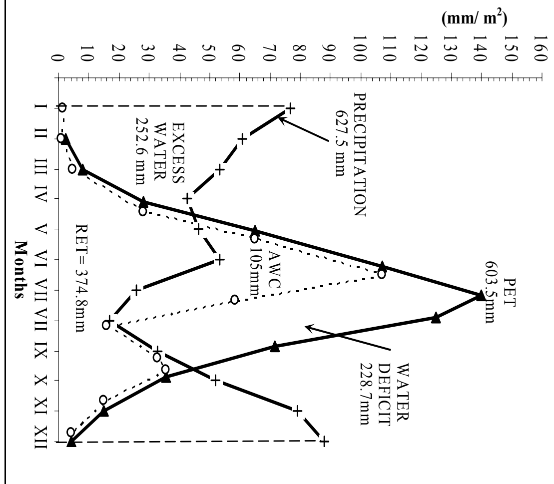
[Altitude= 300-1000 m (in field=800m), Temperature=11.0 ºC, Precipitation=800 mm]



PET mm	PRECIPI-TATION mm	RET mm	WATER DEFICIT mm	EXCESS WATER mm
0.4	97.6	0.4	-	97.2
0.8	77.6	0.8	-	76.8
3.0	68.0	3.0	-	65.0
13.3	54.4	13.3	-	41.1
34.4	59.2	34.4	-	24.8
60.5	68.0	60.5	-	7.5
80.0	32.8	80.0	-	-
73.8	21.6	73.8	-	-
38.5	41.6	38.5	-	-
17.3	66.4	17.3	-	-
6.6	100.8	6.6	-	47.0
1.8	112.0	1.8	-	110.2
Σ 330.4	**800.0**	**330.4**	-	**469.6**
AWC (in soil) = 105 mm / 0.5m^3				

WATER BALANCE OF THE SUB BASIN DURING THE 1929-1970 PERIOD

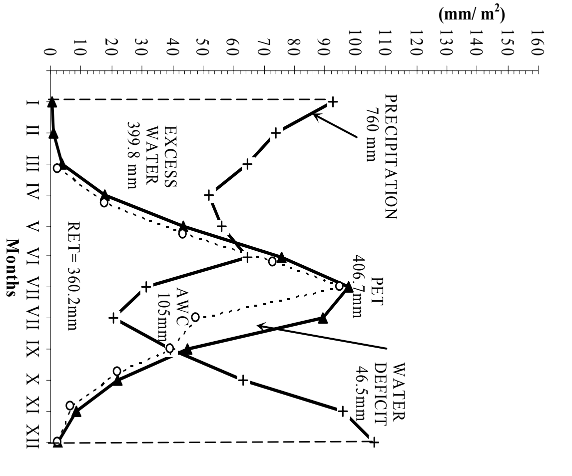
[Altitude < 300 m , Temperature = 13.4 ºC, Precipitation = 627.5 mm]



PET mm	PRECIPI-TATION mm	RET mm	WATER DEFICIT mm	EXCESS WATER mm
1.6	76.6	1.6	-	75.0
2.5	60.9	2.5	-	58.4
7.8	53.3	7.8	-	45.5
28.3	42.7	28.3	-	14.4
65.0	46.4	65.0	-	-
107.1	53.3	107.1	-	-
139.7	25.7	58.3	81.4	-
125.0	16.9	16.9	108.1	-
71.8	32.6	32.6	39.2	-
35.5	52.1	35.5	-	-
14.8	79.1	14.8	-	-
4.4	87.8	4.4	-	59.3
Σ 603.5	**627.5**	**374.8**	**228.7**	**252.6**
AWC (in soil) = 105 mm / 0.5 m^3				

WATER BALANCE OF THE UPPER BASIN DURING THE 1993-2005 PERIOD

[Altitude=300-1000 m (in field=800m), Temperature = (+0.6ºC) 11.6ºC, Precipitation=760 mm]

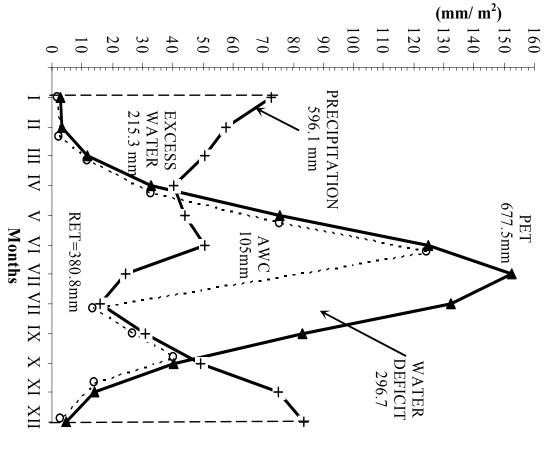


PET mm	PRECIPI-TATION mm	RET mm	WATER DEFICIT mm	EXCESS WATER mm
0.5	92.7	0.5	-	92.7
1.0	73.7	1.0	-	72.7
3.8	64.6	3.8	-	60.8
17.8	51.7	17.8	-	33.9
43.7	56.2	43.7	-	12.5
75.6	64.6	75.6	-	0.0
97.8	31.2	97.8	-	0.0
89.2	20.5	47.9	41.3	0.0
44.7	39.5	39.5	5.2	0.0
22.1	63.1	22.1	-	0.0
8.2	95.8	8.2	-	23.6
2.3	106.4	2.3	-	104.1
Σ 406.7	**760.0**	**360.2**	**46.5**	**399.8**

AWC (in soil) = 105 mm / 0.5 m³

WATER BALANCE OF THE SUB BASIN DURING THE 1993-2005 PERIOD

[Altitude < 300 m , Temperature = (+0.6ºC) 14.0 ºC, Precipitation = 596.1 mm]



PET mm	PRECIPI-TATION mm	RET mm	WATER DEFICIT mm	EXCESS WATER mm
2.6	72.8	2.6	-	70.2
3.5	57.8	3.5	-	54.3
11.8	50.7	11.8	-	38.9
32.7	40.5	32.7	-	7.8
75.6	44.1	75.6	-	-
124.7	50.7	124.2	0.5	-
152.4	24.4	24.4	128.0	-
132.1	16.1	16.1	116.0	-
83.2	31.0	31.0	52.2	-
40.3	49.5	40.3	-	-
13.9	75.1	13.9	-	-
4.7	83.4	4.7	-	44.1
Σ 677.5	**596.1**	**380.8**	**296.7**	**215.3**

AWC (in soil) = 105 mm / 0.5 m³

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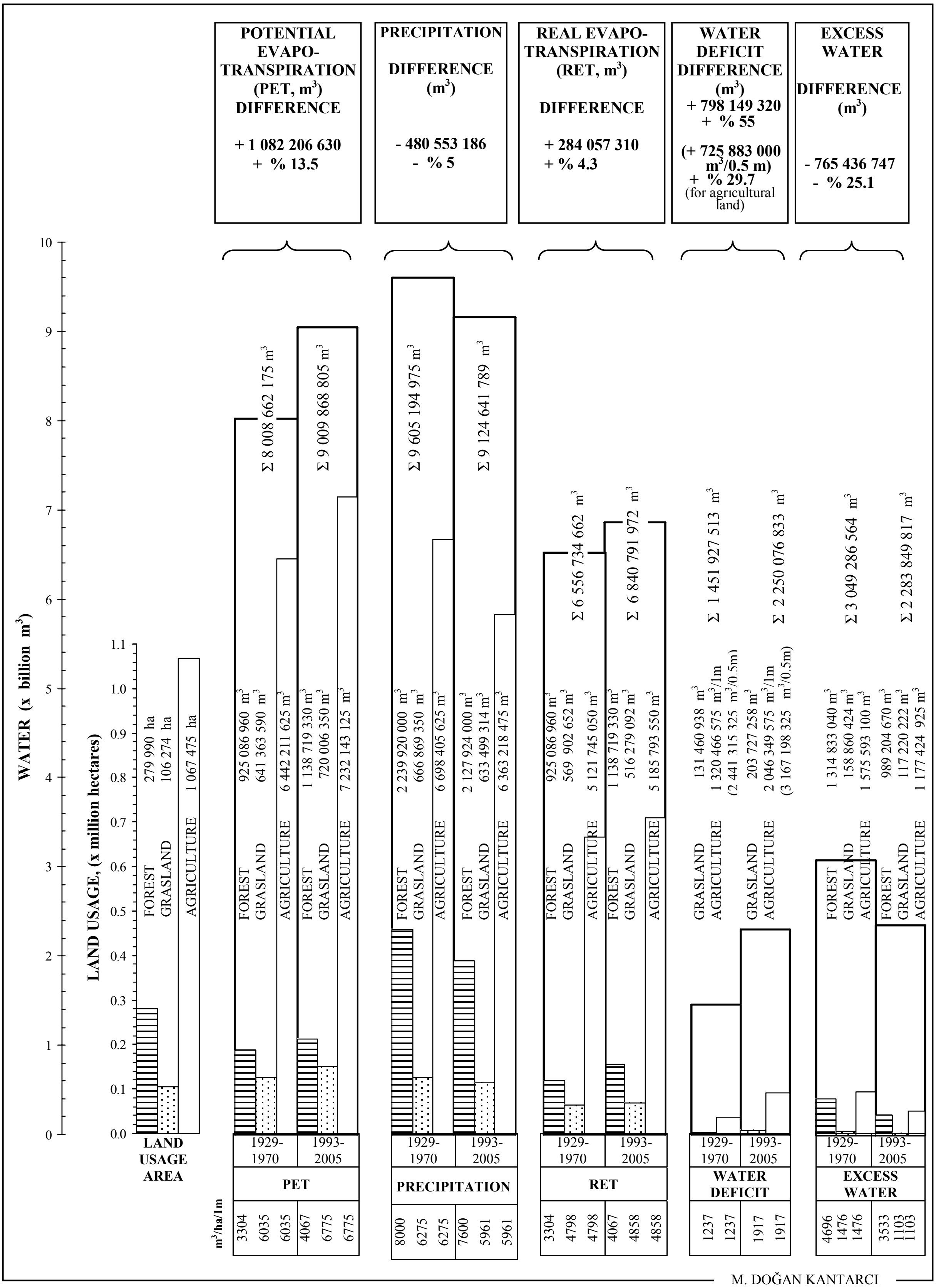
PET mm	RAIN mm	GET mm	WATER DEFICIT mm	EXCESS WATER mm
0.4	97.6	0.4	-	97.6
0.8	77.6	0.8	-	76.8
3.0	68.0	3.0	-	65.0
13.3	54.4	13.3	-	41.1

Figure 4. Water balance according to differences of temperature and precipitation mean values [Some derived data were taken into consideration by +0.6ºC increase in annual mean temperature and -5.0% decrease in precipitation during the 1929-1970 and 1993-2005 (warming) periods].
Soil depth = 1.0 m, non-stony loamy soil, AWC = 210 mm/ m^3 .



WINTER PRECIPITATION AND SNOWFALL IN THE KOREAN COAST

Hyo Choi

Kangnung National University Kangnung, Korea, choihyo@kangnung.ac.kr

ABSTRACT

ın recent years, winter heavy snowfall has frequently occurred in the mountainous coastal region of Korea. Winter precipitation and snowfalls in the mountain and coast of Korea have been investigated from 0000UTC December 6, 2002 through 1200UTC December 9, 2002 and from 0000UTC January 14, 2003 through 1200UTC January 15, using a 3D-numerical model, MM5 V3.7 on a terrain following coordinate system. NCEP data were used as initial input data for the model. 4 days - numerical simulation on meteorological phenomena was made by PC Pentium 4 with one-way triple nesting at Kangnung National University. There were 22 levels in the vertical spread from 10 m to 10 km with sequentially larger intervals with hight. In the numerical process, a triple nesting were made with grid numbers of 125 x 105 with horizontal 27km interval and vertical grid number of 23 in the coarse domain and in the second domain, grid number of 82 x 82 with 9km interval and in the third domain, grid number 61 x 61 with 3km interval. 9km. 2.50 degree interval terrain date was used for the largest domain and then the 0.9km interval data was used for fine mesh domain. MRF method was adopted as boundary layer process in the planetary boundary layer and simple ice method for the prediction was also considered. Horizontal and vertical wind, air temperature, 3 hours - accumulated snowfall amount, mixing ratio inside snow, relative humidity and sensible and latent heat fluxes were evaluated for understanding the formation of precipitation and snowfall events.Winter precipitation in the Korean coast in recent years was highly influenced by pressure system. When a pressure pattern has the characteristics of a high pressure system in the north and a low pressure system in the south of the whole Korean peninsula, north-easterly wind and easterly wind prevail near the Kangnung city in the eastern mountainous coastal region. During the winter precipitation or snowfall period, north-easterly wind and easterly wind prevail in the eastern mountainous coastal region and sensible and latent heat fluxes induce a great amount of evaporation from the sea surface. This wind could drive the moisture transported from the East Sea-coastal area toward the top of mountain in the west and uplifted moisture toward the top of the mountain should be cooled down and saturated, resulting in the formation of ice and rain particles inside low cloud. At this time, streamline on 850hPa level is from north in the East Sea to west passing through Kangnung city and the middle of Korean peninsula and it results in moisture advection from the sea toward the inland of the coastal city. On the path of the moisture advection, clouds forms on GMS satellite picture and this area is correspond to negative vorticity at 500hPa level. Precipitation area coincides with minimum sensible heat flux band or negative value area and latent heat flux band, where snowfall occurs under below 0^0C of air temperature. Precipitation area directly coincides with the area of relative humidity of 100%. Water droplet of cloud below 0^0C of air temperature can form ice phase like snow, as low cloud moves down toward the ground surface of coastal area in the east. Vertical distribution of total cloud mixing ratio combined with temperature distribution gives good information on both the height of cloud formation and the determination of snowfall or rainfall. This research may be applicable to the prevention of forest fire, especially in the mountains and

the management of winter water supply. This work was funded by the Korea Meteorological Administration Research and Development Program under Grant CATER 2006-2308.

TRADING WATER IN REGIONAL MARKETS

Ibrahim Gurer

Gazi University, Engineering and Architectural Faculty, Department of Civil Engineering 06570 Maltepe, Ankara, Turkey gurer@gazi.edu.tr, http://w3.gazi.edu.tr/web/gurer/

ABSTRACT

Since 1990, the climate change and its negative impacts on human lives are discussed more and more loudly. Middle East is known as one of the regions of the world where the water stressed is severely felt. The statistics show that, with this rate of increase in population in Middle East, there will be less and less water per capita in coming years. Water scholars think about the solutions for this limited resource, and the solutions are grouped into two categories; either the desalinization from the sea and the breakish water at a reasonable cost, or trading water from the nearest available source.

In the same region, Turkey is believed to have reasonable amount of water resources at present, and a country strategically located in Middle East. Water as a substance can not be treated as oil, because the sustainability of life without oil is possible but not without water, so `bargaining` and `trading` are not very attractive words in case of water need in the region, especially when the climate change is believed to be in very near future. It is the personal belief of the author that, after supplying the minimum amount of water for the one who need to survive, economizing water and water pricing in coming years will be a more logical approach to provide time to look for realistic solutions rather than to speak up the water wars. Everybody in Middle East has the right of minimum of 125 lt/capita/day, water, but above this amount, one should pay for extra water, either in bottles or in bags.

The quantity and also the quality of the both drinking and irrigation water will be main concerns for the thirsty Middle Eastern if the climate change will make the water scarcity problem more and more severe in the region. The water available for trading should have the quality requirements of World Health Organization (WHO). Turkey is known as a possible water supplier from national rivers at a reasonable cost, if the demand will arise. The demand based management of water in the region, with appropriate progressive pricing structure will help to value this indispensable natural resource.

When the past quarter of a century has been studied, one can see the development in the status of Turkey's plans to export water to Middle East countries at first hand and then to North Africa. In 1986, Turkey proposed technically feasible, pipeline project to divert fresh water of about 6 MCM /day from the national rivers of Seyhan and Ceyhan Rivers located at the south of Anatolia, to the Arab countries in the Middle East. Both of Seyhan and Ceyhan rivers' 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, assuming that local infrastructures of each country would be utilized.

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. Original 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 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 in 2004.

In this paper, with the hope, both projects will be utilized soon before the inverse effects of climate change in the region, the updated technical pictures of these two water sources of Turkey are presented.

Key Words: Climate Change, Middle East, economizing water resources, Turkey, Water Sale, Peace Pipeline project, Manavgat Water Supply project,

INTRODUCTION

The world agreed to prevent "dangerous" climate change at the Earth Summit in 1992, and the first step was the 1997 Kyoto Protocol. Up to now, most of the nations have ratified the Kyoto protocol, which finally came into force during 2005, with modest emission reductions from industrialized countries. It is important for everybody how it will develop in practice. World politicians agree on the development of a new plan for sustainable and environmentally friendly economic growth is needed in all countries in the future. This is a matter of vital importance, regardless of all the short-term issues on political and diplomatic agendas. Disappearing Arctic ice and permafrost, lethal storms and floods in Latin America and Southern Asia, disappearing glaciers in Europe, forest fires and fatal heat waves in many parts of the world are the symptoms of the Climate change. Scientists see it in tree rings, ancient coral and bubbles trapped in ice cores. Climatologists see global warming basically caused by human activities. The long-term issues of ensuring sustainable development and developing sustainable environmental issues and energy supplies are absolutely vital for humanity [1]. So the energy will not be a problem due to ample petroleum resources in Middle East, but the water scarcity problem will be more and more disastrous if some quick solutions can not be found.

Turkey is a country located between Europe and Asia and has a surface area of 779 452 km^2 including the lakes. Turkey has the continental climate at the interior part and the Mediterranean climate at the Aegean and Mediterranean coastal regions. There are seven geographical regions in Turkey. The mean annual precipitation is 642.6 mm and about 70 % falls as snow at eastern and northeastern region of Turkey [2, 3]. This annual precipitation corresponds to 501.0 Km^3 of total water volume. 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, 33.3 Km^3 as the actual consumed volume, and 13.6 Km^3 as exploitable and 6.0 Km^3 as actual consumed volume ground water potential.

It is important to note that 100 % use of this potential is hardly possible. Considering the population of Turkey as nearly 75 million, the existing potential corresponds to an annual per capita water supply of 1460 m^3 that means the drought may create very serious problems. Especially in the near future, because the change in the trend of the climate in the region is alarming.

WATER PROBLEM AND WATER DEMANDS AT PRESENT IN MIDDLE EAST

In Middle East that is one of the poorest areas of the world in terms of water, water problem is increasing day by day. The countries of this area try to meet the need of drinking water by refining the seawater and underground water and pay large costs for it. According to the 1992 data, 15.6 x10^6 m³ salty water is refined per day [4,5]. This situation leads the countries to alternative water resources.

The rate of increase of the population is very much same in all the countries in the Middle East (Table 1). 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 2. The author believes that, with such a high birth rate, and renewable water potentials and estimated quantity of water per capita (Table 2), any country in Middle East will face water shortage problems, and water scarcity during the period of droughts will be

Table 1. Population projections of the Middle East countries [6, 7]

	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	10 403		49 464

Table 2. Renewable water resources and water amount per capita estimates in Middle East countries [8, 9, 10]

Year	**Renewable water potential billion m³**	**Estimated Amount of water in m³/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

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. Birth control will not be disregarded, but may be an alternative on the table.

WATER RESOURCES IN TURKEY and ALTERNATIVE POTENTIALS FOR MIDDLE EAST

Turkey is a country with 770 000 km^2 area and 643 mm mean annual precipitation amount. The precipitation shows a large variation between 250 to 2500 mm (Figure 1).

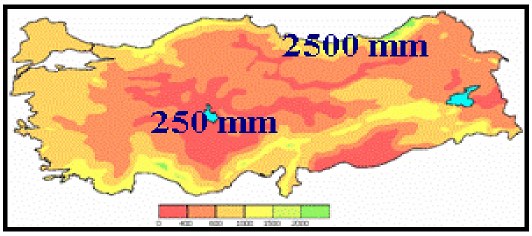


Figure 1. Annual precipitation in Turkey [11]

The useable amount available is only 98 km^3 and that is approximately half of the surface water potential. It is important to note that 100 % use of the potential is impossible. Considering the population of Turkey is nearly 75 million, this potential corresponds to an annual per capita water supply of 1 460 m^3 [12], that means the drought may create very serious problems. Especially the change in the trend of the climate in the region is alarming.

Besides the highly developed desalinization techniques, and reuse of waste water, it may be valuable to bring up some more alternatives as potential sources of water for Middle East.The water potential of the Mediterranean part of Turkey including Aegen coastal zone of Turkey 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 Mediterrenean coast of Turkey, from east to west, include Ceyhan, Seyhan, Goksu, Koprucay, Manavgat, Aksu, and Esencay rivers. All together they have 35x10^9 m^3 annual outflow (Figure 2).

For example there may be other good quality water source from Antalya and Ceyhan basins that constitute approximately 10 % of the surface water resources of Turkey. Actually if all the rivers flowing into Mediterranean Sea from Syrian border to Köycegiz are taken into account, they constitute of about another 20 % of the total water potential of Turkey (Table 3) [13].

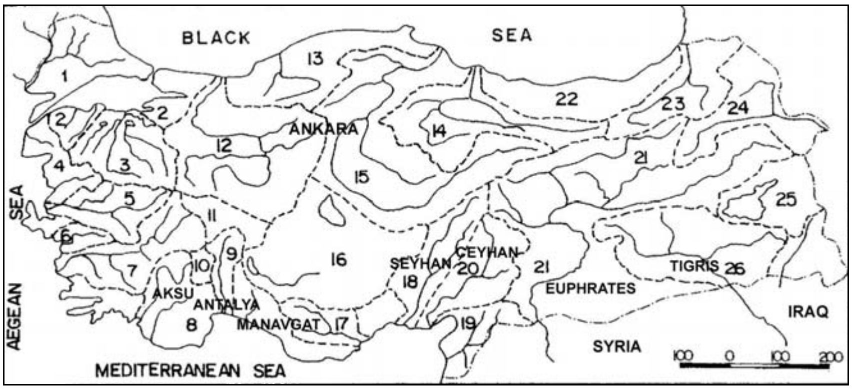


Figure 2. The Water Drainage Basins In Turkey and at Mediterranean Coastal Strip**.**

PEACE PIPELINE PROJECT

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

Table 3. Water and Land Resources of drainage basins located at Mediterranean coastal strip and Euphrates and Tigris Rivers [13]

BASIN				WATER POTANTIALS OF BASIN					SOIL RESOURCES OF BASIN	
				Annual Precipitation (mm)	Flow (km^3)	Discharge $l/s/km^2$	IMPOUNDED WATER WITHIN THE BASIN		Agricultural Plots (hectare)	Irrigable Plain Areas (hectare)
No	Name	Population (1990)	Area (km^2)				Number of Dams	Impounded Water (hm^3)		
8	West Mediterrenean	964890	20 953	875,8	8,93	12,4	22	1 752.99	437 356	406 601
9	Antalya	1 786 426	19 577	1000,4	11,06	24,2	14	2 410.98	451 224	448 111
17	East. Mediterrenean	2 243 551	22 048	745	11,07	15,6	12	10 265.4	438 281	327 790
18	Seyhan	1 814 089	20 450	624	8,01	12,3	17	6 120,62	764 673	714 014
20	Ceyhan	1 510 305	21 982	731,6	7,18	10,7	27	8 235,6	779 792	713 670

to be transported was the surplus at the time of the proposal. As in many new conceptual approaches, the idea attracted both positive and negative reactions. In the year 2005, when the shift in the seasons due to impact of the climatic change in the region is felt more severely, especially the initial political responses since 1986, need a revision, because the technical feasibility of the project did not raise so strong arguments. 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 project consisted of two pipelines

The Western Line was planned to extend 2650 Km along the cities of Hama, Humus, Damascus, Amman, Yanbo and Medine (Figure3.), 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 (Figure3.), 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 [5], so the water need Jordan and Palestine could be answered.
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.

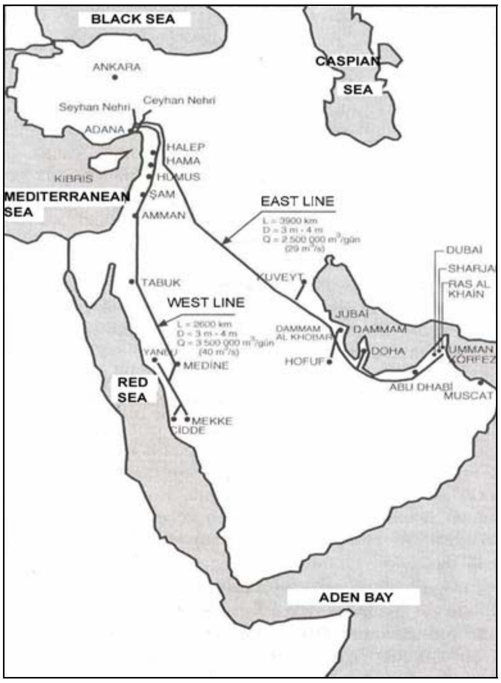


Figure 3. Peace Pipeline Project Concept to Middle East

It might be important to mention about the possibility of using the desalinated water which is computed as US $ 0.68 [14] instead of "Peace Pipeline Project" water. The cost of desalinated water is not so cheap but it is around US $ 1.5 [5].

MANAVGAT WATER SUPPLY PROJECT

Manavgat River that starts from the eastern slopes of Western Taurus Mountain flows into Mediterranean Sea after following about 90 km distance to south. There is Oymapınar and Manavgat Dams over Manavgat River. “Manavgat River Water Supply Project” is located near Manavgat town, Antalya province of Mediterranean Region (Figure 4). The project was started in 1992, it cost approximately 150 million \$ and it was completed in 1999. With this project, 250 000 m^3 refined and 250 000 m^3 raw water, totaling 500000 m^3 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 5.

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.

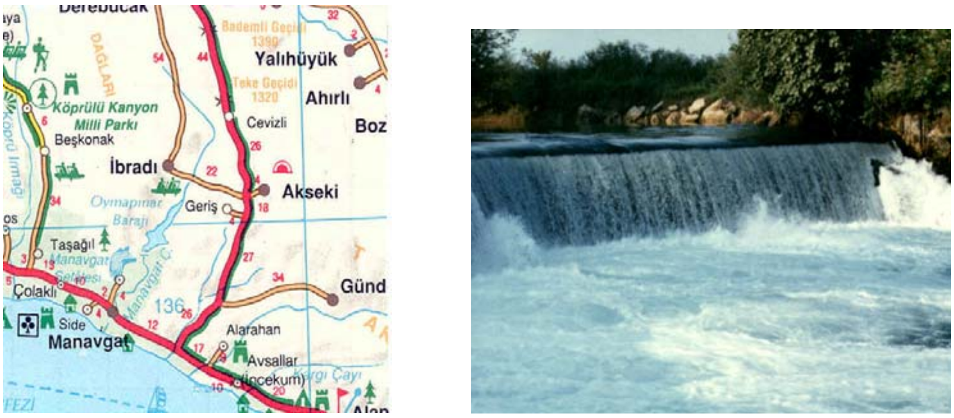


Figure 4. Manavgat river location map and Manavgat River.

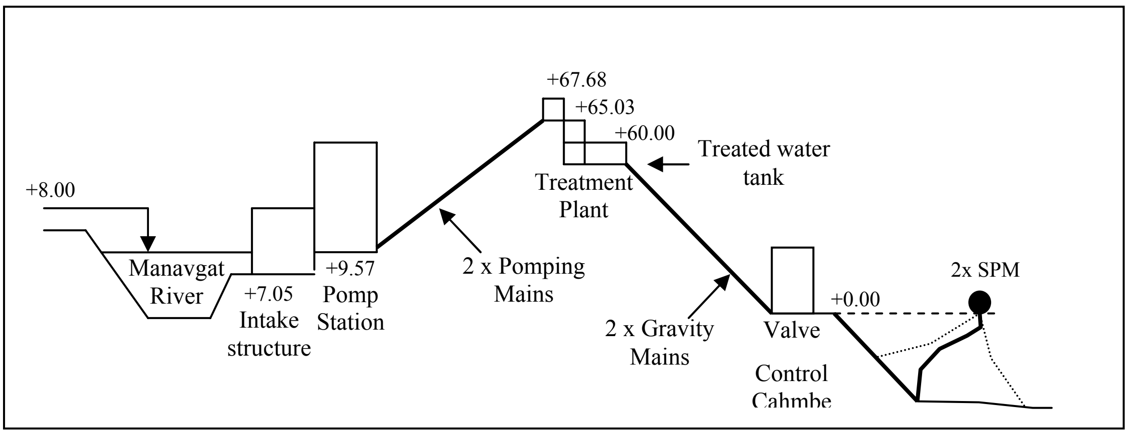


Figure 5. Hydraulic Flow Diagram of Manavgat Project

The Flow Chart of the Manavgat water supply project is given in Figure 6. The details of each step are explained below.

Water intake Structure and Raw Water Pumping Structure

Water intake structure of Manavgat Dam is situated on approximately 800 m downstream of the Manavgat dam. Water taken from the level of + 8.00 m is compressed into balancing and aerating tank that is approximately at the level of + 68 m [15]. Water intake structure is given in Figure 7. and this unit details are given in Table 4.

Table 4. Water intake structure and Raw water pumping structure details [15]

Number of Pumps	:	7 (1 stand –by)	Suction Head	:	2.15 m
Capacity of Pumps	:	967 lt/s	Number of Suction Pipes	:	7
Effective Power	:	900 Kw	Diameter of Suction Pipes	:	800 mm
Total Pumping Head	:	75 m	Diameter of Pumping Pipes	:	700 mm
Number of Air Tanks	:	2	Capacity of Air Tanks (2)	:	100 m^3

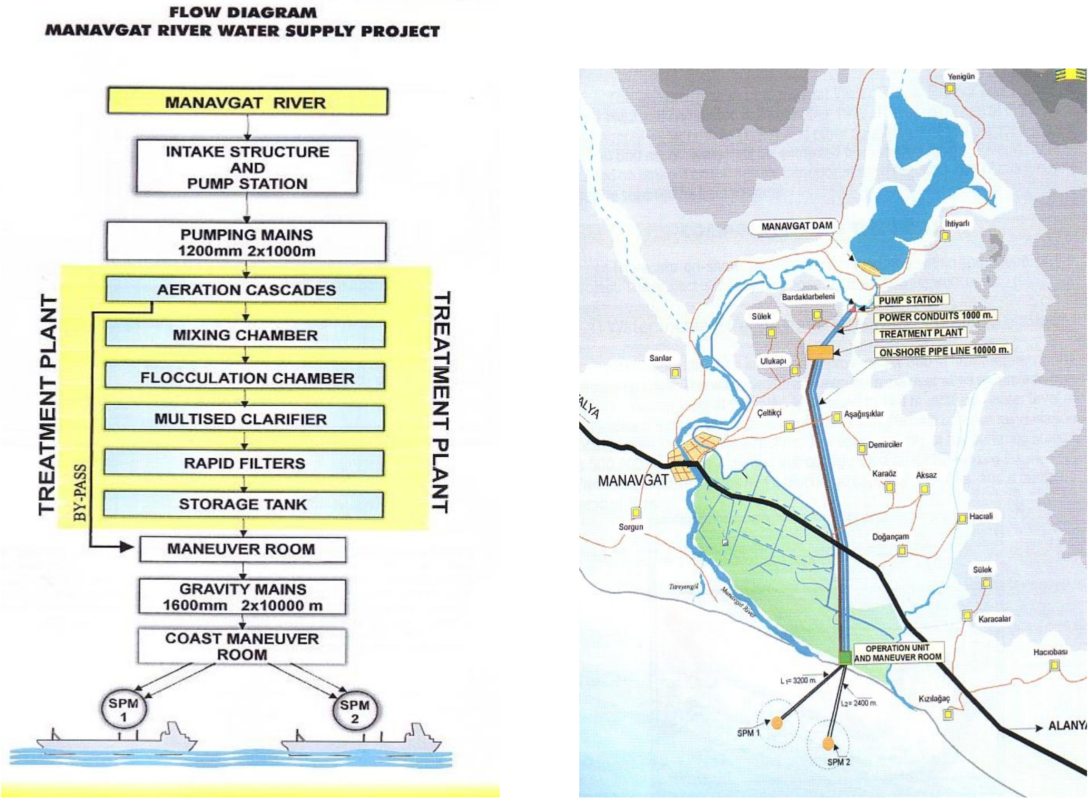


Figure 6: The Flow Chart and the plan view of the Manavgat project [15]

Figure 7. Water Intake Structure [16]

Figure 8. Clarifiers [16]

Pumping Mains

Water taken from raw water pumping mains is transferred to the balancing and aerating tank by means of elevation line. Pumping mains details are given in Table 5.

Table 5. Pumping Mains details [15]

Number of Pipes	:	2
Diameter of Pipes	:	Φ 1200 mm
Wall Thickness	:	8.8 mm
Length of Pipeline	:	1057 m
Type of Pipes	:	Spiral Welded Steel Pipe
Inner Coating of Pipes	:	Icement Added Concrete
Outer Coating of Pipes	:	PE

Treatment Plant

In the south of Bardaklar Beleni quarter of Ulukapı Village of Manavgat, it is situated on the hill that is on the level of 84 m. 250 000 m^3 of the water brought to the balancing and aerating tank by means of elevation line is sent to directly to the coast facilities after the ventilation and pre-chlorination. The rest 250 000 m^3 is processed by both physical and chemical refining phases. In the following, sections of the refinery are shown [15].

- Balancing and aeration chamber
- Rapid mixers and flocculation tanks
- Clarifiers (Clarifiers are given in Figure 8)
- Rapid sand filtration units
- Chlorination contact tank and clean water tank

Gravity Mains

Between the Treatment Plant and Valve Control Chamber and Pumping Station Gravity mains details are given in Table 6.

Table 6. Gravity mains details [15]

Number of Pipes	2	Type of Pipes	Spiral Welded Steel Pipe
Diameter of Pipes	F 1600 mm	Inner Coating of Pipes	Icement Added Concrete
Wall Thickness	12 mm	Outer Coating of Pipes	PE
Length of Pipeline	10 000 m		

Valve Control Chamber And Pumping Station

Valve Control Chamber is designed to load 250 000 m³ refined water and 250 000 m³ raw water or 500 000 m³ raw water simultaneously to two different tanks. Also there are totally 12 pumps with the capacity of 1 m³/sec, 10 mains and 2 substitutes to pump water to the tanks (DSI, 2001). Pumping station is given in Figure 9.

Figure 9. Pumping Station [16]

Off-Shore Pipelines

Between the Valve Control Chamber and the SPM terminals, they consist of 4 pipes whose diameter is 1200 mm, which are placed upon the sea base. Two of these four pipes go to eastern SPM that is 2400 m away from valve control facilities, and the other two go to western SPM that is 3200 m away [15]. Off-Shore pipeline is given in Figure 10.

Spm (Single Point Mooring) Structures

Water coming by means of two pipes shall be transferred to SPM terminals and tankers with the capacity of 60 000 – 250 000 dwt (dead weight ton) by means of floating hoses here. Movement of the SPM terminals is limited by 6 anchors of 12 tons. The ships are attached to SPM terminals from their nose parts [15]. Since the ship-connected parts of SPM terminals can rotate 360˚, the movements of ship conform to the movements of SPM terminals in

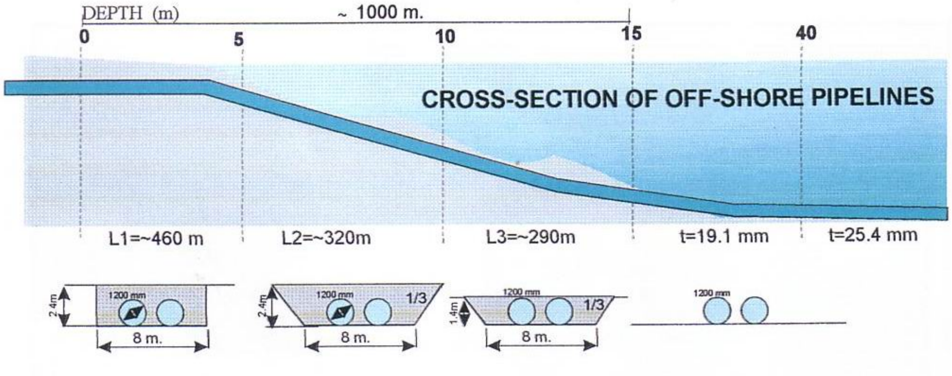


Figure 10. Off-Shore Pipelines [17]

various weather conditions [18]. SPM structure is given in Figure 11. Loading from SPM terminals to the tankers can be performed according to the following options:

1. From one SPM 250 000 m³/day refined, from the other SPM 250000 m³/day raw water,
2. From each pontoon, 250 000m³/day raw water
3. From each pontoon, 125 000 m³/day refined water and total 250000 m³ refined water

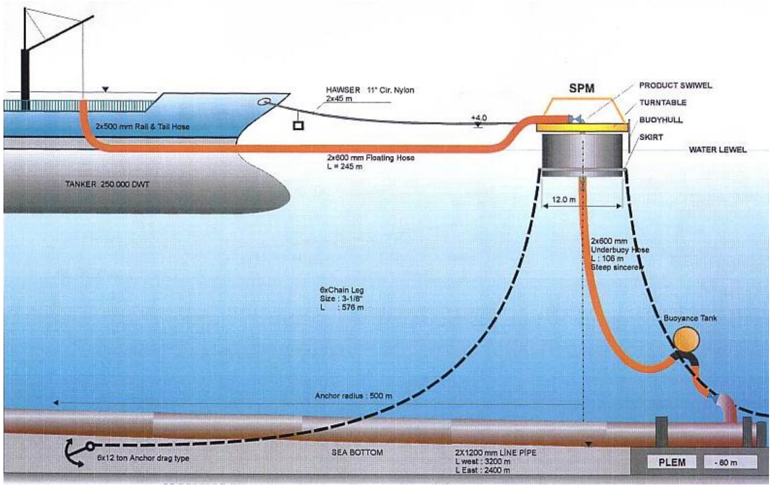


Figure 11. SPM Structure [15]

Raw Water Analysis Report

The water quality standards of the refined water from Manavgat water supply project is given in Table 7, and those standards are compared with other international standards in Table 8. Quality of the refined water conforms to all the specified requirements of Drinking Water Quality Guide of TSE (Turkish Drinking Water Standard) and WHO (World Health Organization).

Possibility Of Water Sale From Manavgat To Alternatives Countries

Turkey, in various meetings, declared that it would provide water when demanded to the other Middle Eastern countries that need water, Northern countries and even to Greek islands. The alternatives for selling water from Manavgat are shown in Figure 12. 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 other than Israel was stated and it was said that Algeria and Morocco were interested in the issue.

Table 7. Raw Water Analysis Report [19].

Period of Analysis **February 1993 April 1999**

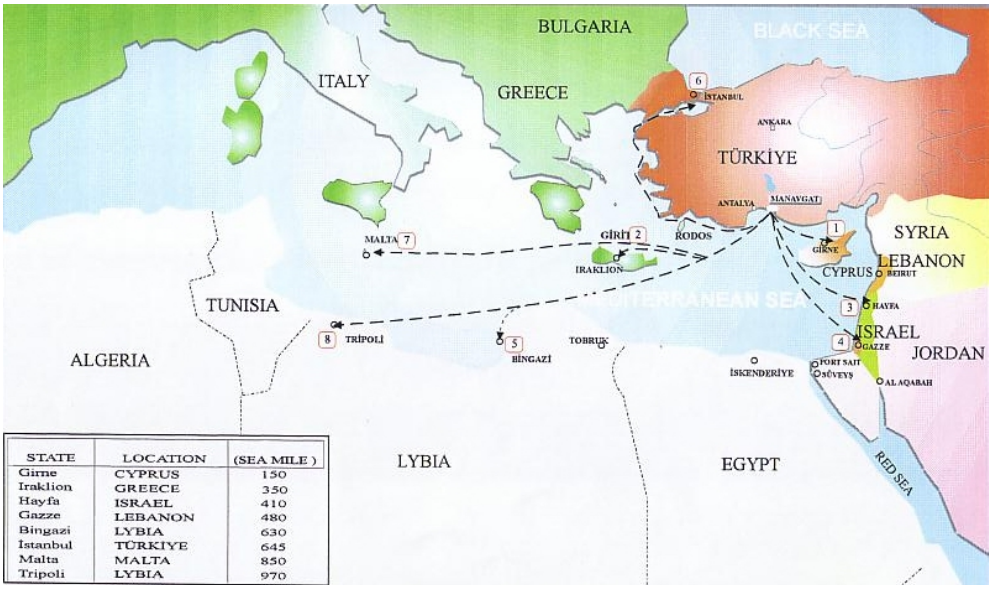
Parameter	***Unit***	***Symbol***	***Average***	Min.	Max.
Flowrate	m^3/sn	Q	147.2	35.78	500.0
Temperature	ºC	t	16.5	8.0	29.0
PH		pH	7.7	7.3	8.0
Elektrical Conductvity	µmhos/cm	EC	284	200	350
Total Dissolved Solids	mg/l	TDS	164	110	210
Suspended Solids	mg/l	SS	9	1	17
Turbidity	NTU	Turb	2.3	0.3	9.5
Color	Pt-Co	Col	5	5	10
Methyl Orange Alkalinities	mg/l $CaCO_3$	M-Al	128.8	76.0	157.5
Phenol-phtalin Alkalinities	mg/l $CaCO_3$	P-Al	0.0	0.0	0.0
Chlorine	mg/l	Cl	11.89	6.39	19.9
Nitrogen of Ammonia	mg/l	NH_4 – N	0.10	0.00	0.54
Nitrogen of Nitrite	mg/l	NO_2 – N	0.000	0.000	0.010
Nitrogen of Nitrate	mg/l	NO_3 – N	0.47	0.00	2.39
Dissolved Oxygen	mg/l	DO	9.63	7.00	13.0
Permanganate Value	mg/l	PV	1.14	0.32	10.72
Biological Oxygen Demand	mg/l	BOD_5	1.36	0.80	2.3
Total Hardness	mg/l $CaCO_3$	TH	158	101	192
Orto Phosphate	mg/l	o-PO_4	0.12	0.00	1.1
Sulphate	mg/l	SO_4	15.41	3.50	23.9
Iron	mg/l	Fe	0.06	0.00	0.2
Sodium	mg/l	Na	1.77	0.69	7.2
Potassium	mg/l	K	0.33	0.10	0.8
Calcium	mg/l	Ca	48.91	24.85	64.1
Magnesium	mg/l	Mg	8.71	2.19	19.2

Till now, water has been being transported only to northern Cyprus. On March 4, 2004, agreement for water purchase was signed in Tel Aviv. According to the agreement, Israel had to purchase 50x10^6 m^3/year water from Turkey for 20 years.

While the cost of the water has not been specified yet, facility outlet price is 0.25 USD, transportation cost is thought to be 0.80 USD. It is not certain yet which country will award the contract for the transportation procedures [20].

For example the transporting of water from Turkey to our neighbors 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. It is not certain yet which country will be awarded the contract for the transportation procedures [21, 16].

Current State Of The Project
Project is ready to work and supply water with its every unit. Also it has been in the scope of privatization of Privatization High Council Decision dated 23.02.2004. It was decided that privatization procedures would be completed in 12 months [22]



STATE	LOCATION	(SEA MILE)
Girne	CYPRUS	150
Iraklion	GREECE	350
Hayfa	ISRAEL	410
Gazze	LEBANON	480
Bingazi	LYBIA	630
İstanbul	TÜRKİYE	645
Malta	MALTA	850
Tripoli	LYBIA	970

Figure 12. Alternative Countries For The Marketing of The Water from Manavgat River Water Supply Project (DSI, 2001)

CONCLUSIONS
In order to solve the water scarcity problem in 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 Turkish national economic resources should also be allocated for the full development of the available water resources.

In Middle East, it is observed that the scarcity of the useable water is not the only problem but also inefficiency in utilization is the other one. An updated technology in the utilization of soil and water resources in Middle East may help to stop the misunderstanding on the figures computed by the technicians.

Also, 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 exporting water from Turkey to Middle East if there will be a demand for it.

As a final word, it can be stated that, for the water scarcity problem of Middle East countries, “Manavgat River Water Supply Project” can be viewed as an alternative ready to put in service, but it is a partial solution.

Table 8: Manavgat River Water Supply Project Comparison Of Selected Parameters Of Raw Water And Treated Water by Various Water quality Standarts [19]

Parameters	Manavgat River Raw Water	Treated Water	EC Drinking Water Standard	WHO Drinking Standard	TS2666 Drinking Water Standard
PH	7,7 – 8,0	PHs-0,2	6,5-8,5	6,5-9,5	6,5-9,2
Electrical conductivity	284-350		400		400-2000
Permanganate Value,mg / lt	1,14-10,72		2-5		2-5
Total Hardness,mg / lt CaCO3	158-192		min.150	100	150
Cholorine, mg Cl / lt	11,9-19,9		25	250	25-600
Ammonium,mg NH4 / lt	0,1-0,54*		0,05-0,5	0,2	0,05-0,5
Nitrite,mg NO2 / lt	0,0-0,1**		0,1		0,1
Nitrate,mg NO3 / lt	0,47-2,39***		25-50	50	25-50
Phosphorous,mg P2O5 / lt	0,0-1,1****		0,4-5,0		0,4-0,5
Turbidity, NTU	2,3-9,3	0,4	0,4-4,0	5	5-25
Iron , mg Fe / lt	0,06-0,2	0,1	0,05-0,2	0,3	0,05-0,2
Aliminium, mg Al / lt		0,05	0,05-0,2	0,2	0,05-0,2
Manganase, mg Mn / lt		0,05	0,02-0,05	0,1	0,02-0,05
Coliform Bacteria , MPN /100 ml		none	None	none	none

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THE CAMI PROJECT: HIGH-RESOLUTION SEISMIC SURVEY TO STUDY SHALLOW AQUIFER

M. Giustiniani[1], F. Accaino[1], E. Del Negro[1], U. Tinivella[1] and D. Nieto Yabar[1]

[1] Istituto Nazionale di Oceanografia e di Geofisica Sperimentale – OGS, Borgo Grotta Gigante 42C, 34010, Trieste, Italy, mgiustiniani@ogs.trieste.it

ABSTRACT
In this paper we describe the application of conventional analysis of seismic data to investigate shallow aquifers located in the Friuli plain (North-East of Italy). This study belongs to a European project entitled "Water-bearing characterization with integrated methods (CAMI)", supported by European community (LIFE). The conventional analysis have consisted of the seismic acquisition and processing of three 2D seismic lines in order to obtain a preliminary geometry and the seismic response of the subsurface. The main purpose of this investigation was to plan the 4D seismic survey. The seismic stacked sections show the presence of multi-layer system in according to available data.

INTRODUCTION

We present the results of the project entitled "Water-bearing characterization with integrated methods (CAMI)", supported by European community (LIFE). This project is giving a contribution to the realization of the 2000/60/CE, using an integrated approach to characterize the hydrographical district and to analyse the environmental impact of the human activities and their sustainability. A pilot project has been tested in order to divide all the UE in hydrographical basins and to let operate all the communitarian programs for the hydrographical basins management, such as: protection, improvement, restoration, sustainability, optimisation of water exploitation without inducing bad environmental, economical and social effects. The aim of the CAMI project is to apply an innovative methodology in order to obtain a wide data set of integrated geophysical and geochemical methodologies to allow: (1) the planning of the amounts of water resources to be assigned to different uses (civil, agricultural, industrial), (2) the impact evaluation on water resources of new industrial and civil settlements, (3) the quantification of underground waters and (4) the research in water ecosystems. The methodology proposed within CAMI project has been initially developed in a pilot area. The site test is located in an area defined by the Tagliamento river (North-East of Italy, Figure 1). This test site was chosen because one important aquifer systems is present and is characterized by a high vulnerability due to the intense farming and industrial activities as well as the intense urbanization.

SEISMIC DATA ACQUISITION

The studied area is located in the Friuli plain where a multi-aquifer system is present. This system is made up of one unconfined body and, at increasing depths, of several confined aquifer bodies of variable thickness and hydraulic permeability, mainly consisting of sandy/gravel material. In particular, two confined aquifers are known very well from direct investigation through exploitation drilled down to 300 m below ground level. The latter aquifers are the main targets of our study: (1) one is very shallow (about 30 m) and needs high frequency seismic source, and (2) the second one is located at about 300 m and relative low frequency seismic source is necessary.

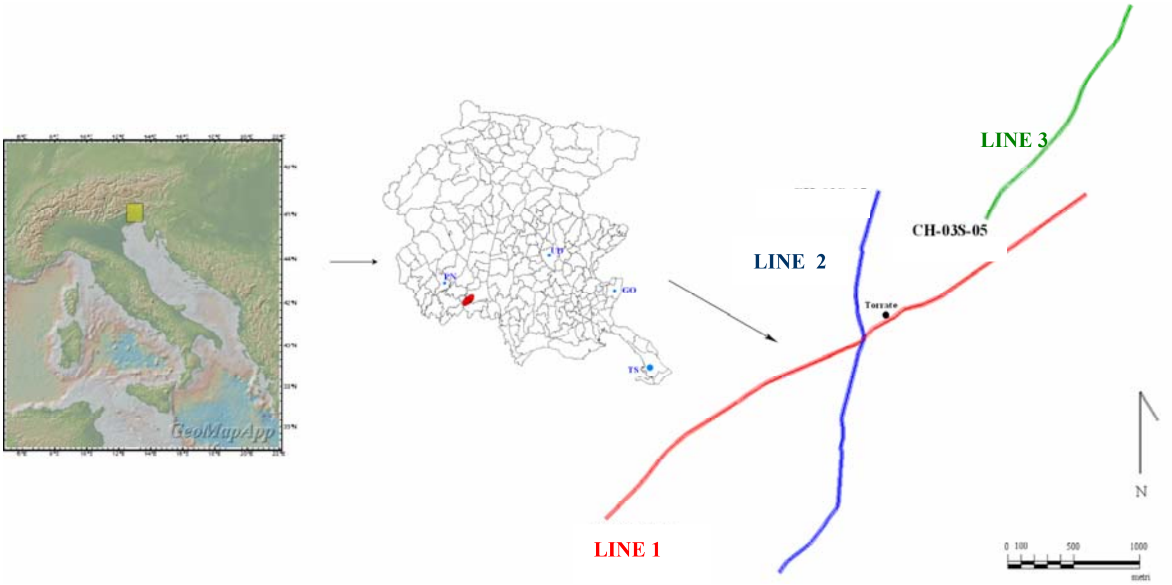

Figure 1. Location map of the 2D seismic lines.

A preliminary modeling study was carried out to design a suitable seismic acquisition survey. A 3D initial multi-parameter (P and S velocities, density and quality factor values of both P and S waves) seismic model was built up by using several shallow stratigraphic wells and information extracted by seismic and geological data available in the studied area [2]. Synthetic seismograms were created by using the commercial software Tesseral (Figure 2). The following step was to carry out a numerical wave simulation of two shots in the seismic model, using a P-wave source for the first and a S-wave source for the second. The purpose of the modeling was to optimize the seismic acquisition configuration to have a sufficient vertical resolution and coverage, and the appropriate characteristics for a faithful tomographic inversion.

Preliminary field tests were performed in order to define the best sweep of the vibroseis and to analyze the ground roll and the environmental noise, particularly strong in a 2D Line 1 (Figure 3), located nearby a main road. To improve the signal/noise ratio, it was decided to shoot two times in each shot position and then we stacked them during the processing phase.

Three 2D seismic lines were acquired as shown in Figure 1; the planning of the seismic lines was influenced by the presence of human buildings and cultivated lands. The seismic source was a Summit acquisition system, with a minimum of 260 active channels. The receiver and shot intervals were respectively 5 m and 10 m, giving a common depth point every 2.5 m. The signal sweep of 12 s length and a frequency range of 10-150 Hz were used to provide 3 s record length after vibroseis correlation. An asymmetrical configuration was selected with a minimum-maximum offset equal to 300 m and 1000 m respectively left and right of the shot. The sampling interval was equal to 1 ms.

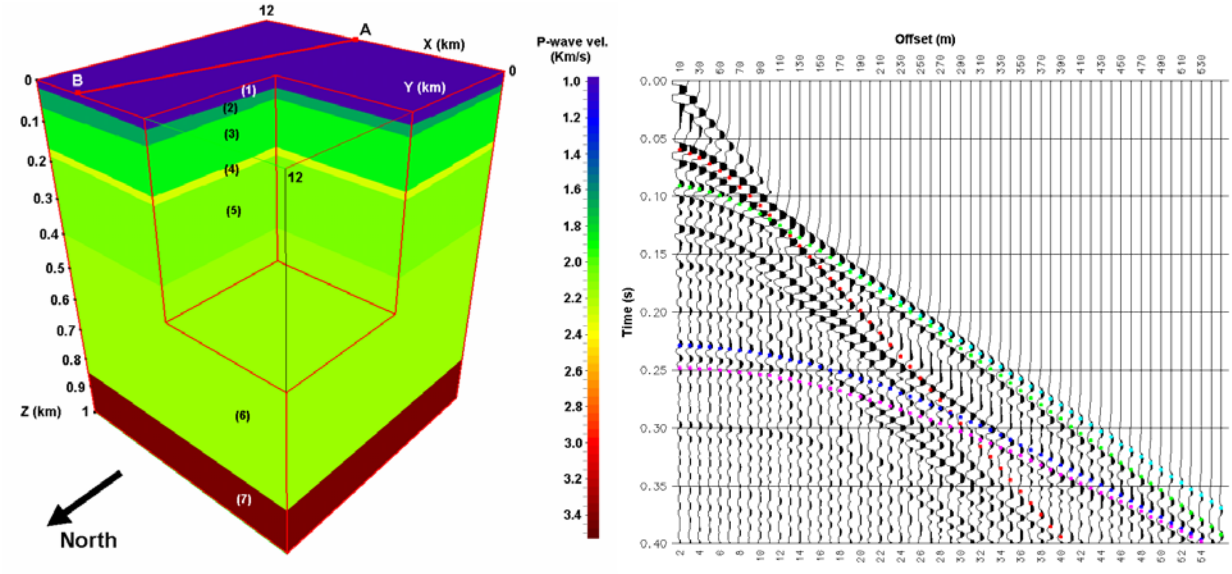

Figure 2. Left: 3D geological model. Right: An example of a synthetic seismogram obtained from petro-physical model.

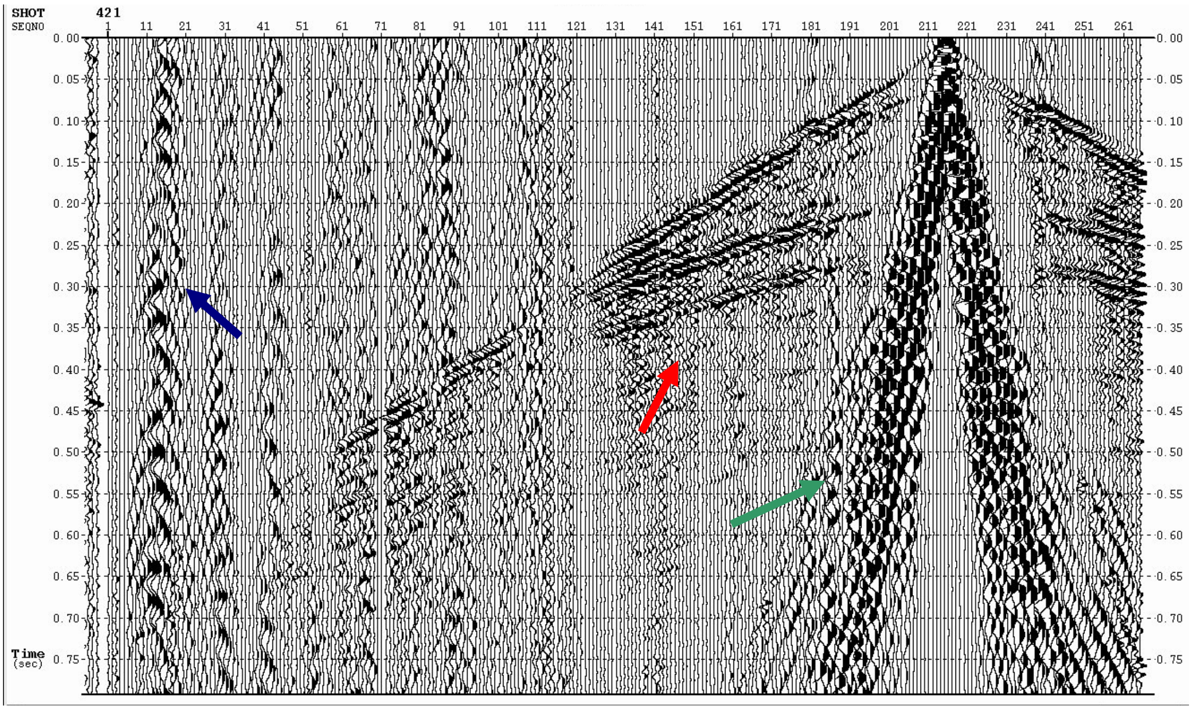

Figure 3 . Example of raw data. The reflections indicated by red arrows are evident. The environmental noise (blue arrows) and the Ground roll (green arrows) are not negligible.

PROCESSING OF SEISMIC DATA

The quality of the raw data was satisfactory, even if the ground roll was strongly evident (see Figure 3). The reflections were very evident from 0.03 s to about 1.1 s, while the refraction events were not always detectable because of velocity inversion caused by the alternance of saturated and unsaturated layers. The seismic lines were located near the main road, so the effects of the running vehicle were evident, in particular on the data of the Line 1. The processing was focalized to remove these undesirable events and to enhance the signal/noise ratio.

First of all, we stacked the shots acquired in the same position in order to attenuate the effects of the noise caused by the random noise. The noisy traces or part of them in which the noise was persistent were zeroed. In this way, we increased the signal/noise ratio. The prefiltering of the data was employed to eliminate the low frequencies connected to the ground roll and to suppress the 50 Hz frequency inducted by the power lines.

After a gain application, data were deconvolved by using a gap deconvolution. The effects of the deconvolution are evident in Figure 4 showing the increase of vertical resolution (Figure 4).

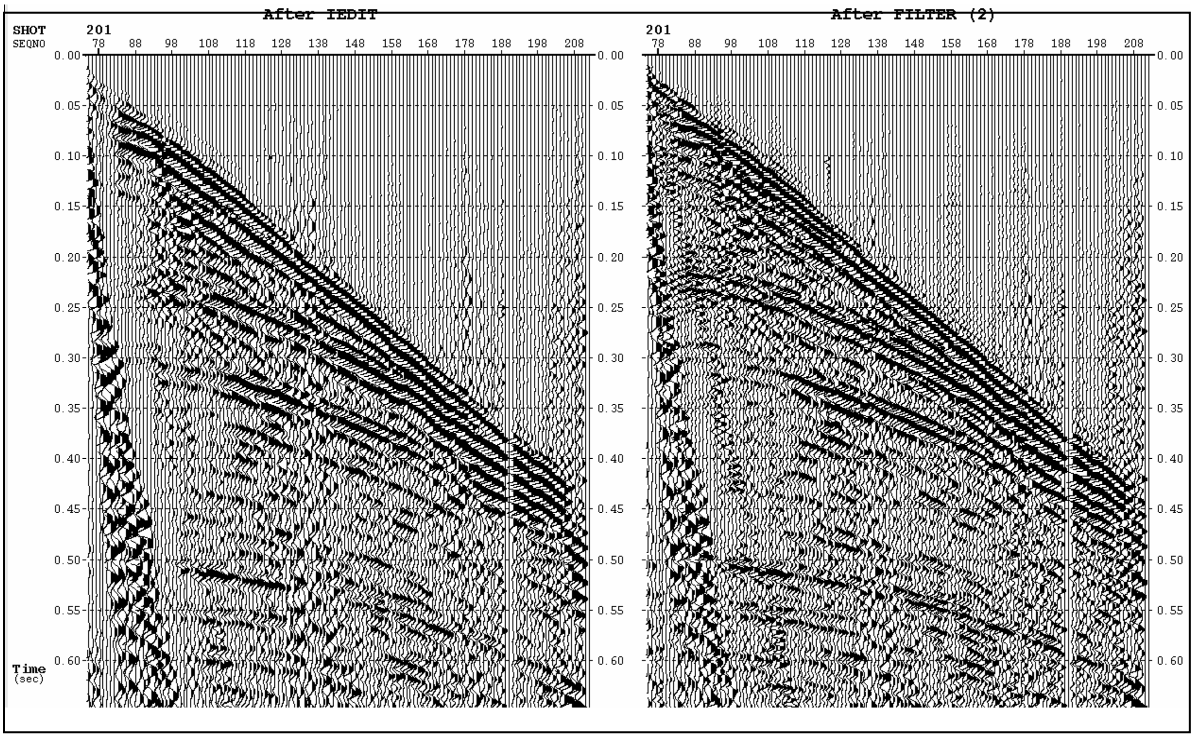

Figure 4. Line 1. Field record before (left) and after gap deconvolution (right). : both reverberations and ground roll were attenuated, allowing the identification of the previously hidden signals.

The velocity field obtained from inversion of the reflected arrivals [1] was used to apply the NMO corrections. The accuracy of the velocity field has allowed having better results after stacking the data.

The investigated area is very flat so just the residual statics were calculated and applied by using the surface consistent algorithm in order to eliminate the effects of the velocity, shots and geophone coupling variations in the near surface. The residual statics calculation was performed one time because of the velocity field accuracy. To attenuate the ground roll, a trimmed mean dynamic dip filter [3,4] was applied in the shot domain.
The data were corrected utilizing the final velocity field and stacked after the application of an external mute function to remove direct arrivals and stretch distorted sample. The f-x deconvolution was carried out to increase the lateral continuity of the signal. The time variant filter was applied to data.

RESULTS AND DISCUSSIONS

The reflection seismic method has allowed detecting the presence of several flat horizons that can be correlated with the stratigraphic wells located in the study area. The two main targets of this study are well recognizable in the seismic stacked sections (Figure 5). As expected, the top of the aquifers (at about 0.03 s and 0.2 s) reveal strong amplitude related to the compressional velocity inversion with a good lateral continuity.

The shallowest aquifer shows strong amplitudes and a continuous signal that could be connected to gravel that contain the shallowest aquifer. In some portions the amplitude is not very strong that could be associated to an increase of fine materials. The second aquifer, one of the main targets of this survey and identified at 500 ms, shows strong amplitude and lateral continuity.

In the studied are the available wells do not intercept the basement so it has been difficult to interpret the deeper horizons. The data underlines the presence of a strong reflector at about 0.5 s that should be interpreted as the bottom of the quaternary deposits in according with others authors [2]. Moreover, the reflection observed at about 0.8 s could be a horizon in the Miocene sediments [2].

The observed amplitudes has confirmed the next planned step consisting in S-wave acquisition by using the vibroseis as seismic source and in advanced seismic processing, such as amplitude versus offset analysis (AVO) [1] to define with high accuracy the elastic parameters of the aquifers.

In conclusion, the satisfactory results obtained in the first 2D acquisition have confirmed the goodness of the procedure used (i) to define the acquisition parameters and (ii) to detect the two main targets. The results of this survey is also a good point of starting for planning the 4D seismic acquisition in the flood and dry seasons.

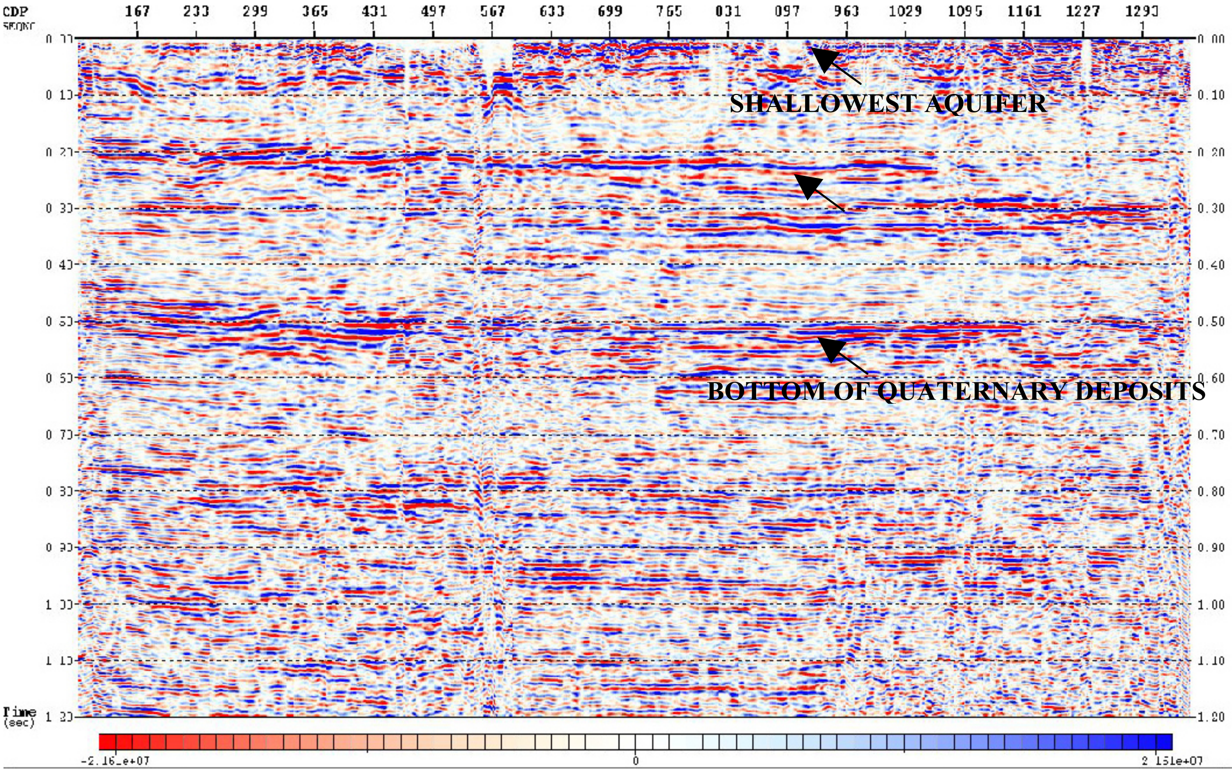

Figure 5. Stacked section of Line 2

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THE HYDROLOGIC CYCLE IN THE EASTERN MEDITERRANEAN FOR A DOUBLE-CO_2 SCENARIO: PRELIMINARY RESULTS IN DOWNCALING FROM ATMOSPHERIC GENERAL CIRCULATION MODEL OUTPUT

Francois Vandenberghe, Andrea Hahmann, Yubao Liu, Dorita Rostkier-Edelstein Scott Swerdlin, Thomas Warner, David Yates, and Wei Yu

Research Applications Laboratory National Center for Atmospheric Research
Boulder, Colorado, USA

INTRODUCTION

The Penn State – National Center for Atmospheric Research (NCAR) mesoscale model, version 5 (MM5), and the Weather Research and Forecast (WRF) model are being used in an effort that will downscale the changes in the precipitation and other components of the water cycle that would result from a doubling of the atmospheric CO_2 in a low-resolution atmospheric general circulation model. The geographic focus area is the eastern Mediterranean and the adjacent countries of the Middle East, where the water supply is currently critical and where the balance between supply and demand could change significantly for future climate scenarios. The first step in this study, reported on here, is the use of the MM5 model to replicate the present-day hydro-climate of the area. To accomplish this, the model has been run for over ten Januaries using NCAR-NCEP (National Centers for Environmental Prediction) Reanalysis Project (NNRP) archived global analyses for lateral-boundary conditions. The comparison of the simulated and observed precipitation is allowing us to adapt the model to this geographic area, and to establish the veracity of the system for use in simulating the regional water cycle. This process of model verification and adaptation for the area will then be repeated with WRF for the entire winter season. After this step, the WRF model will be run for the same period using lateral-boundary conditions from a simulation of the present global climate by the NCAR Community Atmospheric Model (CAM) driven by observed sea surface temperatures and land use. Lastly, the WRF model will be run with the lateral-boundary conditions provided by a double-CO_2 experiment of the coupled ocean-land-atmosphere Community Climate System Model, CCSM. This WRF-model output will be compared with the WRF simulation of the present climate in order to assess the impact of CO_2 doubling on the components of the water cycle in that area. The focus of the study is limited to the winter season when most of the precipitation occurs.

There have been many applications of mesoscale models for downscaling global-model simulations. An example for the geographic area studied here is by Kunstmann et al. (2005), where MM5 was used to downscale from the ECHAM4 global climate model, and MM5 was coupled to a surface hydrological model. The work described here is distinct from that study because our plan is to migrate our effort from the MM5 model to the new community WRF system.

METEOROLOGICAL PROBLEM

This geographic area at the intersection of the subtropics and midlatitudes is very interesting and complex meteorologically, and it is challenging to model. Superimposed on the large-scale processes of this Mediterranean climate are mesoscale effects related to the complex coastline and nearby mountains (see terrain elevation on the model grids in Fig. 1). Also, there are strong near-coastal gradients in observed precipitation (see Fig. 2), the position of which have huge hydrologic consequences. If these gradients shift position in new climate regimes, the implications for water supply are great.

MODELING APPROACH

The model being used in the initial part of this study is MM5 because it has been much more-thoroughly tested than WRF. When we have confirmed the ability of MM5 to successfully reproduce the major aspects of the current hydroclimate, we will transition to WRF. Figure 1 shows the computational area of our system of two, interacting grids, along with the terrain elevation. The grid increment of the outer grid is 45 km and that of the inner grid is 15 km. Our current effort focuses on a single month, January. The NNRP data set will allow us to calculate 40-year climatology.

The verification of the simulations is presently in the context of cyclone pressure and precipitation fields. The pressure field is used to define storm-track and central-pressure errors. The modeled precipitation fields are being evaluated in terms of monthly total amounts, the inter-annual variability in monthly totals, and the frequency of extreme rain rates. An objective is to obtain satellite-derived estimates of precipitation over the Mediterranean, to complement the rain-gage data that are presently being used.

RESULTS

Results are presented here for two Januaries, rather for the 40-year climate, because some of the years remain to be simulated. Figure 3 shows the observed (rain gage) and simulated January precipitation for 1992 on the inner, fine grid. Even though the simulated precipitation over the Sea cannot be verified, the model does very well in defining 1) the strong coastal gradient in the Levant and 2) greater precipitation over the southern Mediterranean (coastal Egypt) than over the northern Mediterranean (coastal Turkey). Cyclone track verification is presently underway. Figure 4 is for 1995 and applies to the larger area of the outer grid. It can be seen that, for this January, the model correctly places the heavier rainfall over the north coast, compared to the south, even though the model apparently produces too much rainfall in some areas.

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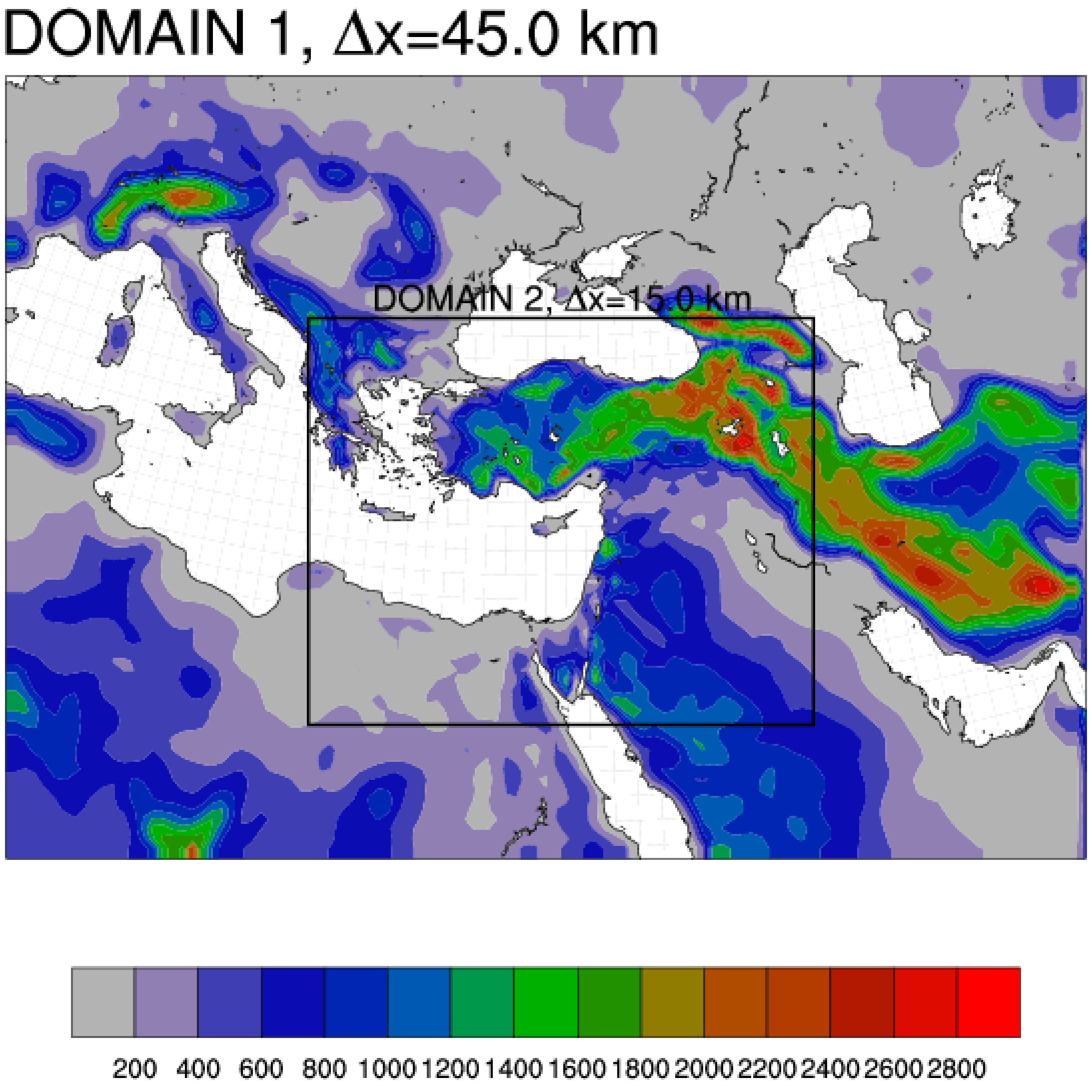

Figure 1. Computational areas of the nested model grids, and the grid increments. Also shown is the terrain elevation (colors). The color bar units are meters above sea level.

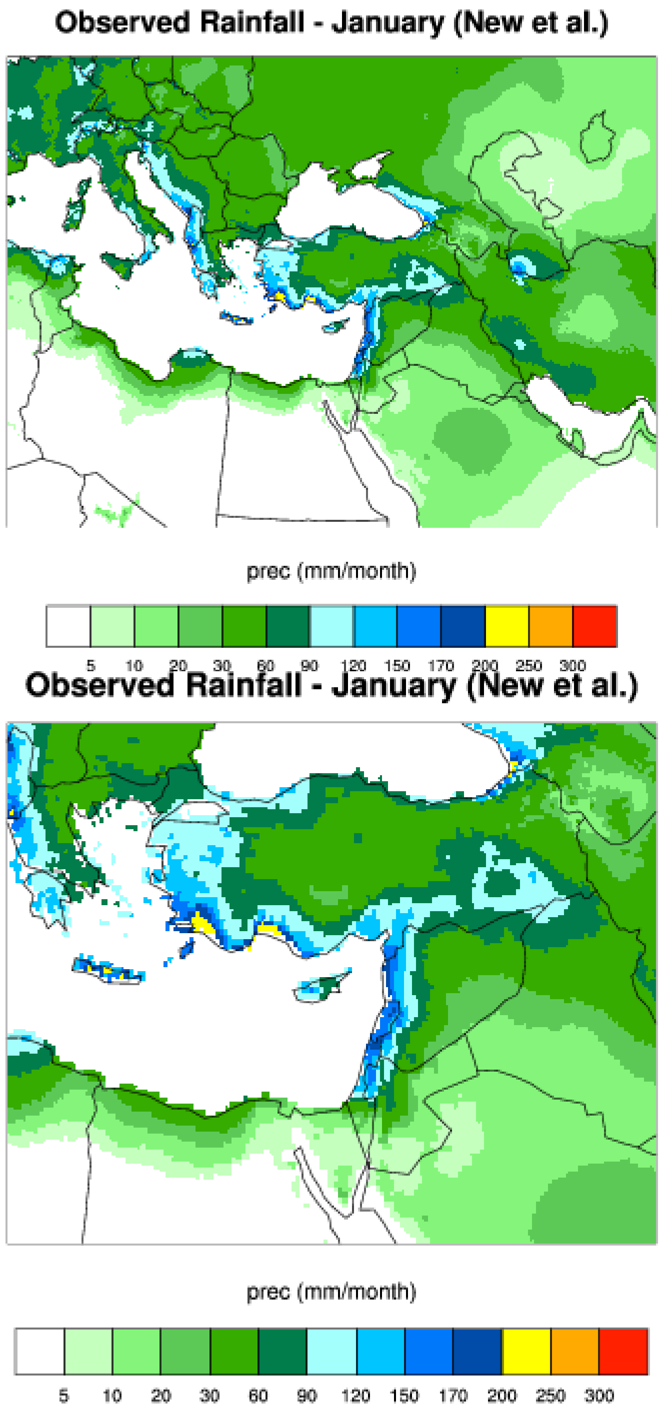

Figure 2. Observed January precipitation over land for the computational area of the model outer grid (top) and inner grid (bottom), based on New et al. (2002).

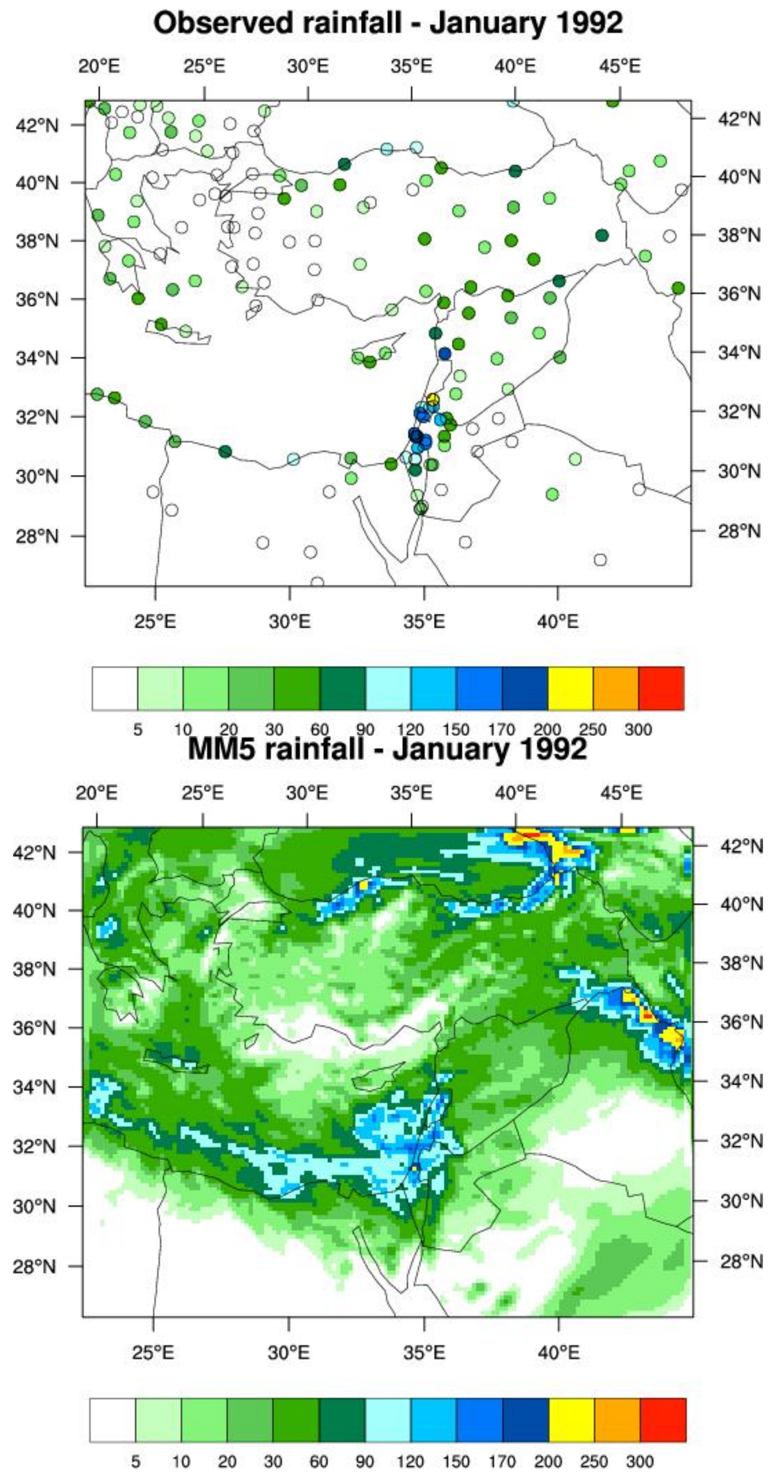

Figure 3. Comparison of observed (top) and model-simulated (bottom) January precipitation for 1992 on the inner, fine grid. The monthly total amounts are in millimeters.

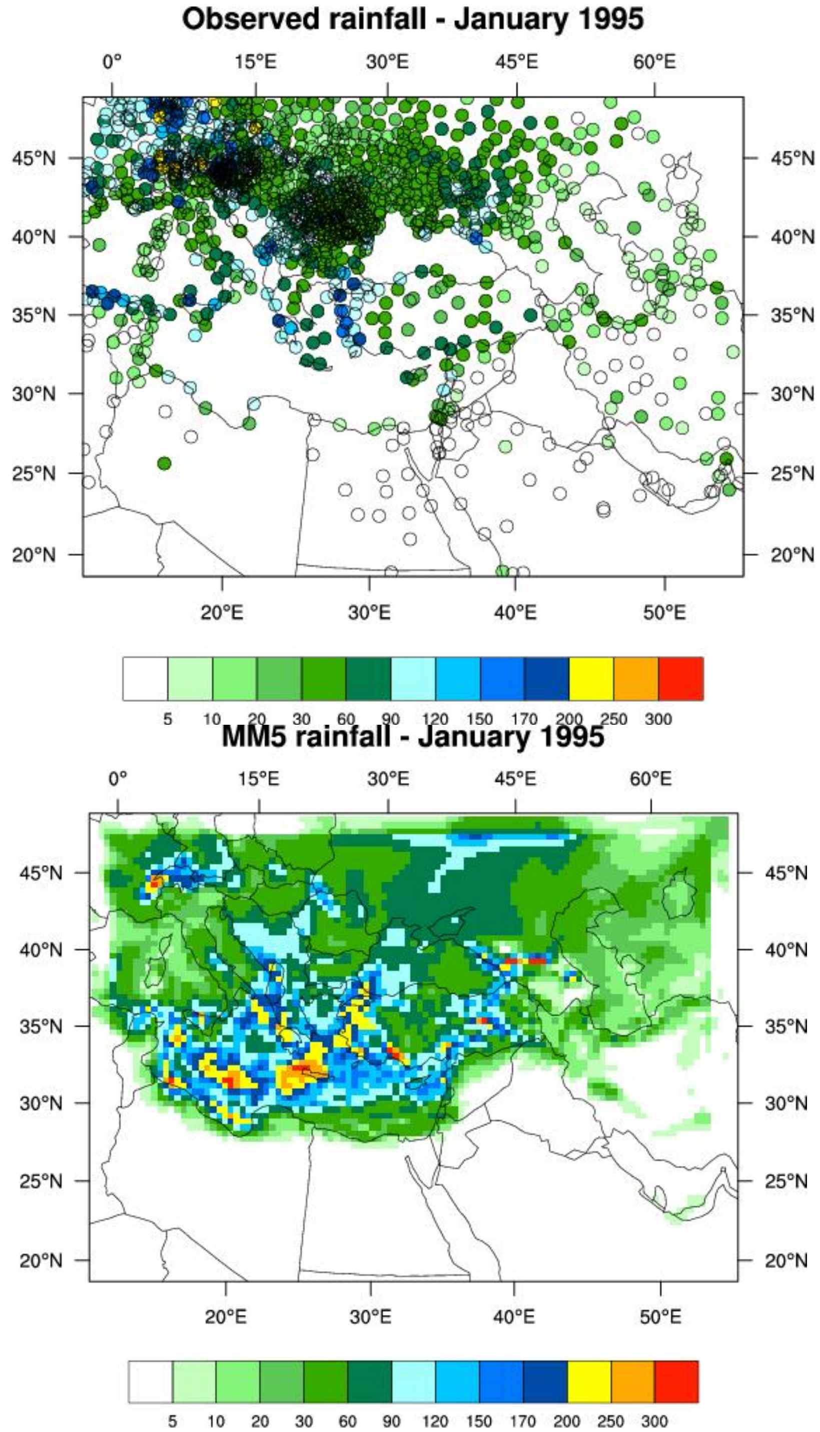

Figure 4. Comparison of observed (top) and model-simulated (bottom) January precipitation for 1995 on the outer, coarse grid. The monthly total amounts are in millimeters.