Climate Change Projections for Turkey: Three Models and Two Scenarios

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Abstract

"A scenario is a coherent, internally consistent and plausible description of a possible future state of the world". The name "representative concentration pathways – RCP's" are referred to as pathways in order to emphasize that their primary purpose is to provide time-dependent projections of atmospheric greenhouse gasses (GHGs) concentrations. In this study, it is intended to reveal the possibilities of future climate change for Turkey and its surrounding region. HadGEM2-ES, MPI-ESM-MR and GFDL-ESM2M Global Circulation Models' RCP4.5 and RCP8.5 scenarios outputs were used in the study. Temperature and precipitation projections were produced from these outputs, based on domain with 20 km resolution, covering period between 2016 and 2099 and using regional climate model RegCM4.3.4 and with dynamic downscaling method. According to the models results, it is expected that an increase between 1°C and 6°C in mean temperatures of Turkey. In generally precipitation amount shows a decreasing except winter season. Although there is no regular decreasing or increasing trend throughout projection period, it attracts more attention irregularity of precipitation regime.

Key words: *RCP, HadGEM2-ES, MPI-ESM-MR, GFDL-ESM2M, RegCM.*

1. Introduction

The importance of climate in human life is associated with positive or negative effects of the climate in social and economic life and how it affects (Demir et al., 2013; Demircan et al., 2014 [a],[b],[c]). Many institutions and organizations, both national and international, governmental and non-governmental, have made efforts to determine the possible changes in climate and the impacts of these changes correctly, in order to provide a sustainable life to people.

The most important of these efforts are climate modelling studies. Variables representing environmental conditions may include in the model in more detail in conjunction with the development of technology. From the 1970s climate models began to be used with the proliferation of the use of computers for scientific purposes. In the first climate model studies, climate was modelled according to only the atmosphere and observed parameters in the atmosphere. By the developments in science and technology, land surface, oceans, sea ice, sulphate aerosols,

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carbon cycle, atmospheric chemistry and dynamics of vegetation and other factors have been new parameters that are important inputs to climate models. Both with the development of science and technology and with the guidance of IPCC, climate change studies started to produce more accurate outcomes.

In 2006, a few results from the regional climate model RegCM3 were available for the last 30 years of the 21st century, and this was only under one SRES scenario. Substantial progress has been made since 2006. In recent years, substantial climate simulation studies focusing on Turkey and its surrounding region have been developed. Regional climate change simulation based on the IPCC A2 scenario over the Eastern Mediterranean for the last 30 year of the 21st century were developed by Önol and Semazzi (2009). The climate research group of the Eurasia Institute of Earth Sciences at ITU has carried out a downscaling experiment for Turkey using the outputs of the emission scenario simulations of three different GCMs (TFNC, 2013).

Since 2006, a number of regional climate simulation studies have been carried out on Turkey (its sub regions or with its surrounding region). Regional climate change simulations based on the SRES scenarios have been performed by Krichak et al. (2007), Gao and Giorgi (2008), Turuncoglu et al. (2007), Önol and Semazzi (2009), Zanis et al. (2009), Black et al. (2010), Sen et al. (2011), Demir (2011), Ozdogan (2011), Bozkurt and Sen (2011), Önol (2012), Bozkurt et al. (2012), Önol and Unal (2012), Bozkurt and Sen (2013), Önol et al. (2013). In these studies, they found a temperature increase for the entire region and a decrease in annual precipitation in generally.

State Meteorological Service (SMS) has produced climate projections by downscaling method using global models within the scope of Coupled Model Inter-comparison Project Phase 5 (CMIP5). For the climate projections, new generation concentration scenarios of IPCC AR5 (Representative Concentration Pathways, RCP) were used. As well as, a project titled "The Effect of Climate Change on Water Resources Project - TECCWRP" was started in 2013 by the Ministry of Forestry and Water Affairs, General Directorate of Water Management (GDWM) (SNCT, 2016).

Since 2010, a number of regional climate simulation studies have been carried out for Turkey (its sub regions or with its surrounding region) with new scenarios. Regional climate change simulations based on the RCP scenarios have been performed by Demir et al. (2013), Demircan et al. (2014 [a],[b],[d]), Ozturk et al. (2014), Turp et al. (2014), Unal et al. (2015), Gurkan et al. (2015), Yıldırım et al. (2015), Ozturk et al. (2016), Gurkan et al. (2016), Demiroglu (2016). In these studies, they found a temperature increase for the entire region and decrease of annual precipitation in general.

Climate is the average weather conditions experienced in a particular place over a long period. Climatological normals are averages for consecutive periods of 30 years which are calculated from climatological data (Demircan et al., 2013; Demircan et al., 2014 [a],[b],[c],[d]). Using climate normals are very important tool to provide a standard base for preparing global assessment and climate monitoring studies. The reference period of climate; 1961-1990, 1971-2000 and 1981-2010 as climate normals are used by scientists, national climate services and international institutions in climate monitoring, climate trends, climate change and modelling studies.

2. Method

The study involves projection of climate parameters that are produced by using regional climate model (RegCM4.3.4) with dynamic downscaling method based on RCP4.5 and RCP8.5 scenarios from outputs of 3 Global Circulation Models (HadGEM2-ES, MPI-ESM-MR and GFDL-ESM2M).

HadGEM2 is a comprehensive Earth-System Model developed by Hadley Centre of UK Met Office. The standard atmospheric component has 38 levels extending to ~40km height. Horizontal resolution is 1.25° latitude and 1.875° longitude (~112.5 km) (MetOffice, URL). MPI-ESM-MR is a comprehensive Earth-System Model developed by Max Plank Institute (MPI) for Meteorology (MR mixed resolution). It is one of the preferred model in CMIP5 studies. This version resolution is 63 level in horizontal (approximately 1.9° (~210 km) on a Gaussian grid) and 95 level in vertical. GFDL-ESM2M is a comprehensive Earth-System Model developed by National Oceanic and Atmospheric Administration (NOAA) Geophysical Fluid Dynamics Laboratory (GFDL). It is one of the preferred model in CMIP5 studies. This version resolution is 2.5° longitude, 2° latitude (~220 km) in horizontal and 24 level in vertical.

Climate models are the primary tools available for investigating the response of the climate system to various forcings, for making climate predictions on seasonal to decadal time scales and for making projections of future climate over the coming century and beyond (IPCC, 2013). Regional Climate Models (RCMs) are limited-area models with representations of climate processes comparable to those in the atmospheric and land surface components of Atmosphere-Ocean General Circulation Models (AOGCMs), though typically run without interactive ocean and sea ice. RCMs are applied over a limited-area domain with boundary conditions either from global reanalyses or global circulation model output. RCMs are often used to dynamically 'downscale' global model simulations for some particular geographical region to provide more detailed information (Laprise, 2008; Rummukainen, 2010; IPCC, 2013). By contrast, empirical and statistical downscaling methods constitute a range of techniques to provide similar regional or local detail. Parameterizations are included in all model components to represent processes that cannot be explicitly resolved; they are evaluated both in isolation and in the context of the full model. Atmospheric models must parameterize a wide range of processes, including those associated with atmospheric convection and clouds, cloud-microphysical and aerosol processes and their interaction, boundary layer processes, as well as radiation and the treatment of unresolved gravity waves.

Representative Concentration Pathways – RCP's

"Experts Meeting" with broad participation was organized by the IPCC in September 2007 for a new approach for climate change scenarios to be used in the IPCC 5th Assessment Report. In this context; a new set of new emission/concentration scenarios were produced. These new emission/concentration scenarios, named Representative Concentration Pathways (RCPs), have specified characteristics. (Table 2.1) (TSMS, 2015).

Table 2.1.
Types of Representative Concentration Pathways (RCP's) (Based on IPCC, 2007)

Name of RCP's	Radiative Forcing	Time	Pathway shape	Concentration (ppm)	Emissions (Kyoto Protocol's greenhouse gases)
RCP 8.5	> 8.5 W/m^2	in 2100	Rising	> ~1370 CO2-eq in 2100	Rising continues until 2100.
RCP 6.0	~6.0 W/m^2	at stabilization after 2100	Stabilization without overshoot	~850 CO2-eq (at stabilization after 2100)	Decline in the last quarter of century
RCP 4.5	~4.5 W/m^2	at stabilization after 2100	Stabilization without overshoot	~650 CO2-eq (at stabilization after 2100)	Decline from the mid-century
RCP3-PD*	~3.0 W/m^2	peak at before 2100 and then decline	Peak and decline	peak at ~490 CO2-eq before 2100 and then decline	Decline in the first quarter of century

Global Models and Data Sets

This study contains the results of the project named "Climate Projections with New Scenarios for Turkey". In this context, three (HadGEM2-ES, MPI-ESM-MR and GFDL-ESM2M) Global Circulation Models' data were used based on RCP4.5 and RCP8.5 scenarios. The period 1971-2000 was defined as the reference period and the period 2016-2099 was defined as the future period.

Table 2.2.
Data sets and periods

GCMs Data Set	Reference Observation Data Sets (RODSs)	Reference Period	Projection Period
HadGEM2-ES MPI-ESM-MR GFDL-ESM2M	Climate Research Unit (CRU) University of Delaware (UDEL)	1971-2000	2016-2099

Dynamic Downscaling: RegCM4

RegCM4 which is developed by International Centre for Theoretical Physics in Italy (ICTP) was used in the study (Giorgi et al., 1993 [a],[b]). This model is a limited area atmospheric models that is consisting of the basic equation, hydrostatic, compressible and sigma pressure levels. RegCM4's model physic uses BATS ground surface model (Dickinson et al., 1993), non-local boundary layer diagram (Holtslag et al., 1990), the radiation scheme of the NCAR CCM3 (Kiehl et al., 1996), parameterizations for ocean surface fluxes (Zeng et al., 1998), the explicit moisture scheme of (Hsie et al., 1984), a large-scale cloud and precipitation scheme which accounts for the subgrid-scale variability of clouds (Pal et al., 2000) and various options for cumulus convection (Anthes, 1977; Grell, 1993; Emanuel and Zivkovic-Rothman, 1999).

One-way nesting method was used to downscale from Global Circulation Models to study domain. Resolution of HadGEM2-ES is allowing a direct downscaling to 20 km. On the other hand, resolution of MPI-ESM-MR and GFDL-ESM2M is not allow directly downscaling. Firstly, MPI-ESM-MR and GFDL-ESM2M was downscaled to 50km than they were downscaled to 20 km from 50 km outputs. A domain with 20 km horizontal resolution which has 130x180 grid-scale and 18 pcs sigma level was used for this study. Cumulus convection parameterization of Emanuel on the land and Grell on the sea was used as convective precipitation scheme for projection study.

The Sensitivity and Control Tests

For control tests of GCMs, regional model was run for the period of 1971-2000 and results were compared with RODSs (Table 2.2). Averages of temperature and daily total precipitation that based on seasonal and annual scale were compared with RODs. Results shown in Table 2.3.

Table 2.3.

Seasonal and annual averages of temperature and precipitation within the reference period of 1971-2000 for regional climate model simulation and grided observations

SEASONS	Temperature (°C)					Precipitation (mm/day)				
RCM/ODS	HadGEM	MPI	GFDL	CRU	UDEL	HadGEM	MPI	GFDL	CRU	UDEL
WINTER	0.436	0.525	-0.949	0.561	-0.076	2.159	2.524	1.728	2.126	2.353
SPRING	8.294	8.628	6.996	9.712	9.309	2.622	1.92	2.24	1.973	2.098
SUMMER	20.792	19.603	17.343	20.859	20.7	0.947	0.417	1.769	0.685	0.742
AUTUMN	10.412	11.003	8.404	12.48	11.961	1.83	1.284	1.206	1.332	1.454
AVERAGE	9.987	9.95	7.956	10.906	10.474	1.886	1.532	1.736	1.530	1.664

As seen in Table 2.3, the average temperature results which were obtained with using downscaling from the reference period (1971 to 2000) data of three global models (HadGEM2-ES, MPI-ESM-MR and GFDL-ESM2M) were compared with RODSs. HadGEM2-ES's data are seen an overlap with observation data in winter and summer and lower about 1.5°C in spring and autumn from RODSs. MPI-ESM-MR and GFDL-ESM2M's data are seen lower between 1-4°C from RODSs in all season except winter. In winter, MPI-ESM-MR value is overlap with RODSs. According to annual average temperature comparison of Turkey, HadGEM2-ES and MPI-ESM-MR's results are lower about 1°C than CRU and UDEL's observation data sets. There is a difference about 3°C between GFDL-ESM2M's results and RODs (CRU and UDEL).

Daily precipitation results which were obtained with downscaling from the reference period (1971 to 2000) data of three GCMs (HadGEM2-ES, MPI-ESM-MR and GFDL-ESM2M) were compared with RODSs. In particularly, downscaled data of HadGEM2-ES in winter and MPI-ESM-MR in autumn are seen overlap with RODs. The results data of MPI-ESM-MR in winter season, HadGEM2-ES in autumn, GFDL-ESM2M and HadGEM2-ES in spring are higher than RODSs. The results data of MPI-ESM-MR in spring and summer and GFDL-ESM2M in winter and autumn are lower than RODs. Considering the overall average, HadGEM2-ES and GFDL-ESM2M'results are higher between 0.2-0.4 mm than RODSs and MPI-ESM-MR's results are overlap with RODSs.

3. Results

In this study, we tried to put forth the possibilities of future climate change for Turkey and its surroundings with the regional climate model RegCM4. RCP4.5 and RCP8.5 scenarios outputs of HadGEM2-ES, MPI-ESM-MR and GFDL-ESM2M Global Circulation Models have been used in the study. Projection's domain includes Turkey and its surrounding region with 20 km grid resolution. Using these outputs, temperature and precipitation projections that covering the period 2016-2099 have been produced for Turkey. Future projection period (2016-2099) is divided into three groups 2016-2040, 2041-2070 and 2071-2099 respectively. Seasonal mean values were obtained for these three periods. Differences between reference period (1971-2000) and future periods were calculated for the parameters of temperature and precipitation.

Temperature and Precipitation Projections According to RCP4.5 Scenario

Temperature and precipitation values were obtained from RCP4.5 scenario of HadGEM2-ES, MPI-ESM-MR and GFDL-ESM2M Global Circulation Models with using dynamic downscaling method. Then differences of temperature and precipitation were calculated between reference period (1971-2000) and future periods. Anomalies of temperature and precipitation are visualized as seasonally for all periods. In generally all of models show an increasing in temperature and a decrease in precipitation with different anomaly values and spatial patterns from now to until end of the century. (Figure 3.1 and 3.2).

In the first period (2016-2040), temperature anomalies are predicted to increase about 0.5-1.5oC for MPI-ESM-MR and GFDL-ESM2M, and about 1.5-3oC for HadGEM2-ES. HadGEM2-ES's anomaly values are higher than other two models. It would be an increase about 2-3oC in summer temperature, except northeast of Eastern Anatolia Region and east of Black Sea Region (Figure 3.1).

In the second period (2041-2070), according to temperature outputs of HadGEM2-ES it might be an increase about 2-3°C in spring and autumn temperatures and an increase up to 4°C in summer temperature. Generally, in MPI-ESM-MR and GFDL-ESM2M, anomalies are between 1-2°C throughout the country and over the seasons (Figure 3.1).

In the last period (2071-2099), it would be an increase about 2°C in winter temperature and 3°C in spring and autumn temperatures. It would be an increase up to 4°C in summer temperature in the Southeast Anatolia Region and coastal part of the Aegean Region. In MPI-ESM-MR and GFDL-ESM2M, anomalies are between 1-2°C throughout the country and over the seasons in generally and increasing up to 3°C in south and southwest part of Anatolia in summer season (Figure 3.1).

When looking at precipitation projections, according to HadGEM2-ES in the first period (2016-2040), it would be an increase about 10% - 40% in precipitation during the winter months in the coast part of the Aegean, Central Black Sea and East Anatolia Regions. Conversely, other two models show an increase up to 20% in precipitation in interior and north part of country and a decrease in the coast part of the Aegean. Unfortunately it is expected to decrease about 20% in the precipitation in the spring in a large part of the country. HadGEM2-ES and MPI-ESM-MR show similar pattern in spring and summer precipitation. GFDL-ESM2M shows generally an increase in most of the country in spring. In autumn, all models show different precipitation pattern (Figure 3.2).

In the second period (2041-2070), according to HadGEM2-ES and MPI-ESM-MR in generally, it would be a decrease about 20% in winter precipitation in East Anatolia, Southeast Anatolia and central and eastern parts of Mediterranean Region. It would be a decrease about 30% in precipitation except Eastern Black Sea coast according to GFDL-ESM2M in generally. In spring, it would be a decrease in interior part of Anatolia according to all models. According to all models it is expected that would be a decrease around 30% in precipitation in summer season in Eastern Anatolia where summer rainfall is important. It is expected to an increase up to 50% in Marmara Region according to both HadGEM2-ES and MPI-ESM-MR. In autumn, models show a decrease in generally throughout Turkey except coastal part of the Aegean Region (Figure 3.2).

In the last period (2071-2099), it would be an increase about 10% in precipitation especially along coastal line except south part of the Anatolia in winter. It would be a decrease about 20% in spring precipitation except coastal part of the Anatolia according to HadGEM2-ES and MPI-ESM-MR. It would be an increase about up to 40% along to country except south part of the Anatolia according to GFDL-ESM2M. In summer season precipitation it would be a decrease up to 60% except coastal part of the Aegean, Marmara and Black Sea Regions in all models. It would be a decrease in autumn precipitation throughout the country except west part and some small part of interior of country in MPI-ESM-MR and GFDL-ESM2M in generally (Figure 3.2).

Temperature and Precipitation Projections According to RCP8.5 Scenario

Temperature and precipitation values were obtained from RCP8.5 scenario of HadGEM2-ES, MPI-ESM-MR and GFDL-ESM2M global circulation model with dynamic downscaling method for project domain. Then differences between reference period (1971-2000) and these periods were calculated for temperature and precipitation. Anomalies of temperature and precipitation are visualized as seasonally for all periods. In generally all of models show an increasing in temperature and a decrease in precipitation with different anomaly values and spatial patterns from now to until the end of the century. (Figure 3.3 and 3.4).

In the first period (2016-2040), it would be an increase about 3°C especially in spring and summer temperatures in HadGEM2-ES and about 0.5-2°C in MPI-ESM-MR and GFDL-ESM2M (Figure 3.3).

In the second period (2041-2070), it would be an increase about 2-3°C in the winter temperature, about 3-4°C in autumn and spring temperatures and about 5°C in summer temperature in HadGEM2-ES. It would be an increase about 1-2°C in the winter temperature, about 1.5-3°C in autumn and spring temperatures and about 5°C in summer temperature in MPI-ESM-MR and GFDL-ESM2M in generally. (Figure 3.3).

According to HadGEM2-ES in the last period (2071-2099), it would be an increase about 3-4°C in west of Trabzon and Mersin line, about 4-5°C in east of Trabzon and Mersin line in winter temperature. With similar pattern in MPI-ESM-MR and GFDL-ESM2M it is expected to an increase about 2-4°C in the winter, 2-5°C in spring temperature. It would be an increase about 6°C in spring and autumn temperatures especially in South East Anatolia Region in HadGEM2-ES. It would be an increase exceeding 6°C throughout the country in HadGEM2-ES and up to 6°C partly in MPI-ESM-MR and GFDL-ESM2M (Figure 3.3).

In the first period (2016-2040), it would be an increase in precipitation during the winter months except west part of the Marmara, east part of the Mediterranean, southeast part of the Central Anatolia and west part of the Southeast Anatolia Regions in HadGEM2-ES. It would be an increase in precipitation in winter in north part of Anatolia in MPI-ESM-MR and GFDL-ESM2M. It would be a decrease in spring precipitation in west of Mersin-Ordu line in HadGEM2-ES and GFDL-ESM2M and in northeast part and Marmara Region in MPI-ESM-MR. It would be an increase about 40% in summer precipitation except west part of the Mediterranean Region in HadGEM2-ES. It would be a decrease in summer precipitation throughout the country in MPI-ESM-MR and GFDL-ESM2M except some local part. It would be a decrease in autumn precipitation throughout the country in HadGEM2-ES and GFDL-ESM2M. (Figure 3.4).

In the second period (2041-2070), it would be an increase in precipitation during the winter months except south part of Anatolia in HadGEM2-ES. It would be an increase in precipitation in winter in north part of Anatolia in MPI-ESM-MR and GFDL-ESM2M. It would be a decrease in spring season except west part of the Aegean, west and east part of the Black Sea and northern part of East Anatolian Regions in HadGEM2-ES and GFDL-ESM2M. It would be a decrease in spring precipitation throughout country in MPI-ESM-MR. It would be a decrease about 50% in summer precipitation throughout the country except west and east part of the Black Sea, coastal part of the Aegean and the Marmara Regions in HadGEM2-ES. It would be a decrease in summer precipitation throughout the country in MPI-ESM-MR and GFDL-ESM2M except some local part. In the autumn precipitation, it would be a decrease throughout the country in generally in HadGEM2-ES and GFDL-ESM2M and except northwest costal and southeast part of Anatolia in MPI-ESM-MR (Figure 3.4).

In the last period (2071-2099), it would be an increase in precipitation during the winter months except south part of Anatolia in HadGEM2-ES and MPI-ESM-MR and eastern part of Black Sea Region in GFDL-ESM2M. It would be a decrease about 20% in spring precipitation except coastal part of the Aegean Region, west and east part of Black Sea Region and northern part of East Anatolia Region in HadGEM2-ES and GFDL-ESM2M and a decrease in throughout the country in MPI-ESM-MR. It would be a decrease in summer precipitation except coastal part of the Aegean, Marmara and Black Sea Regions in HadGEM2-ES. It would be a decrease in summer precipitation throughout the country in MPI-ESM-MR and GFDL-ESM2M in generally. Generally in autumn it would be generally a decrease up to 50% throughout the country in all models (Figure 3.4).

Considering to increasing in temperature and precipitation together in both RCP scenarios: The increase in temperature may cause turn the precipitation type from snow to rain during the winter. Furthermore, it could be caused to early snow melting in spring. The reason of increased precipitation amount would be much more evaporation than normal which caused by increasing temperature in spring and summer season in coastal area. When it is considered with convective characteristic of spring and summer precipitation, it could be caused extreme precipitation events in mentioned regions. And also increasing in temperature could be caused to extreme weather events such as storm, hail and waterspout.

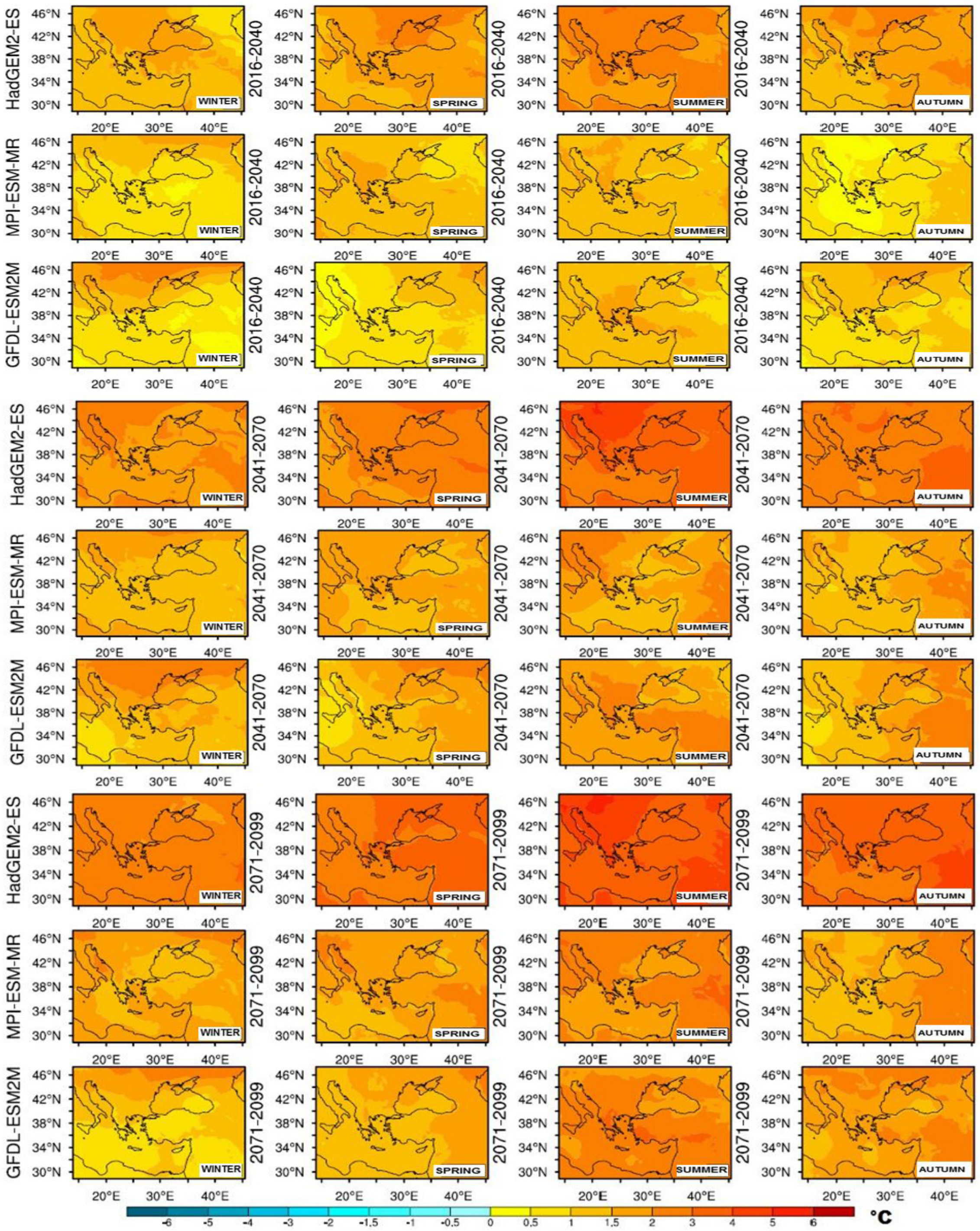

Figure 3.1. Temperature projections according to RCP4.5

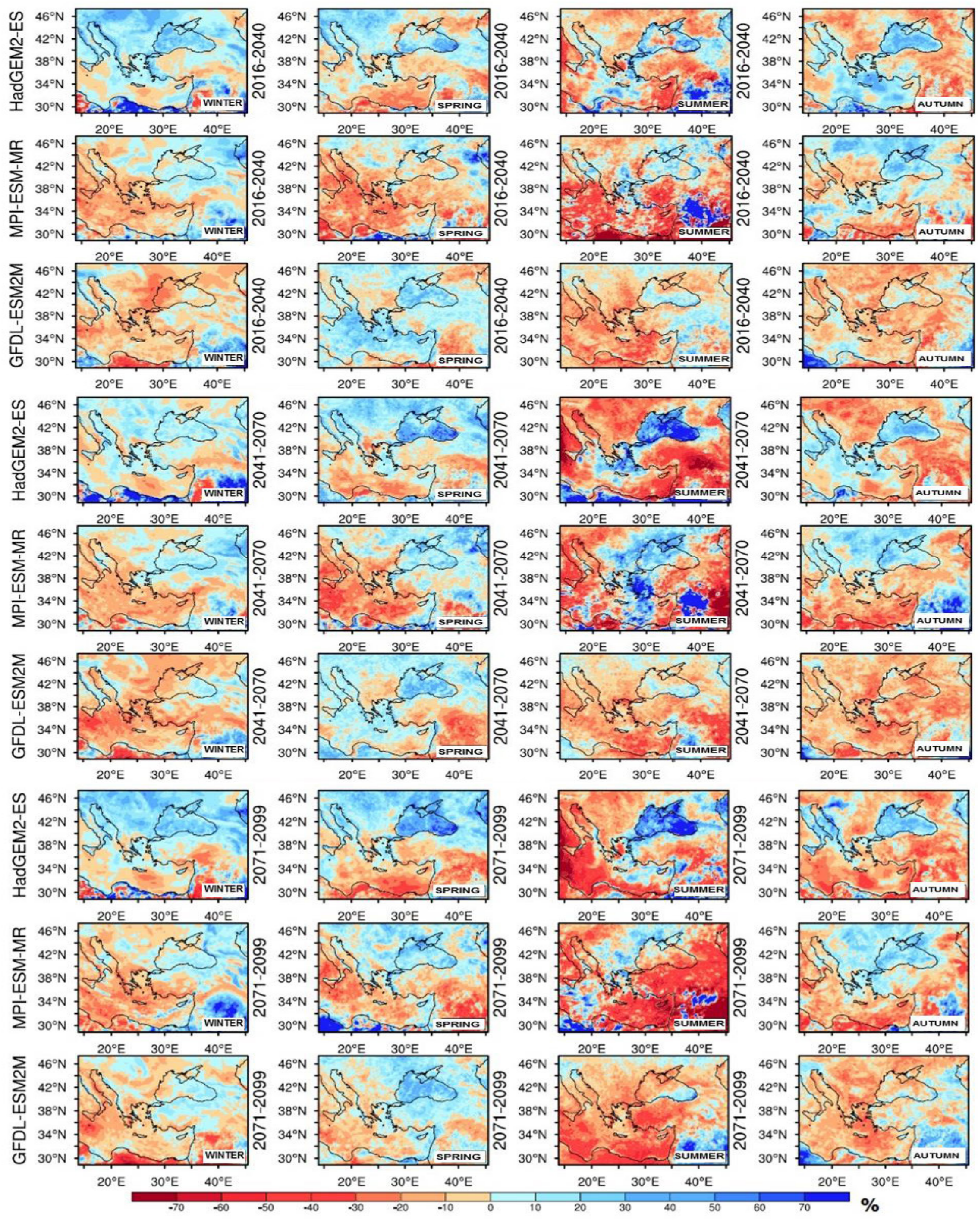

Figure 3.2. Precipitation projections according to RCP4.5

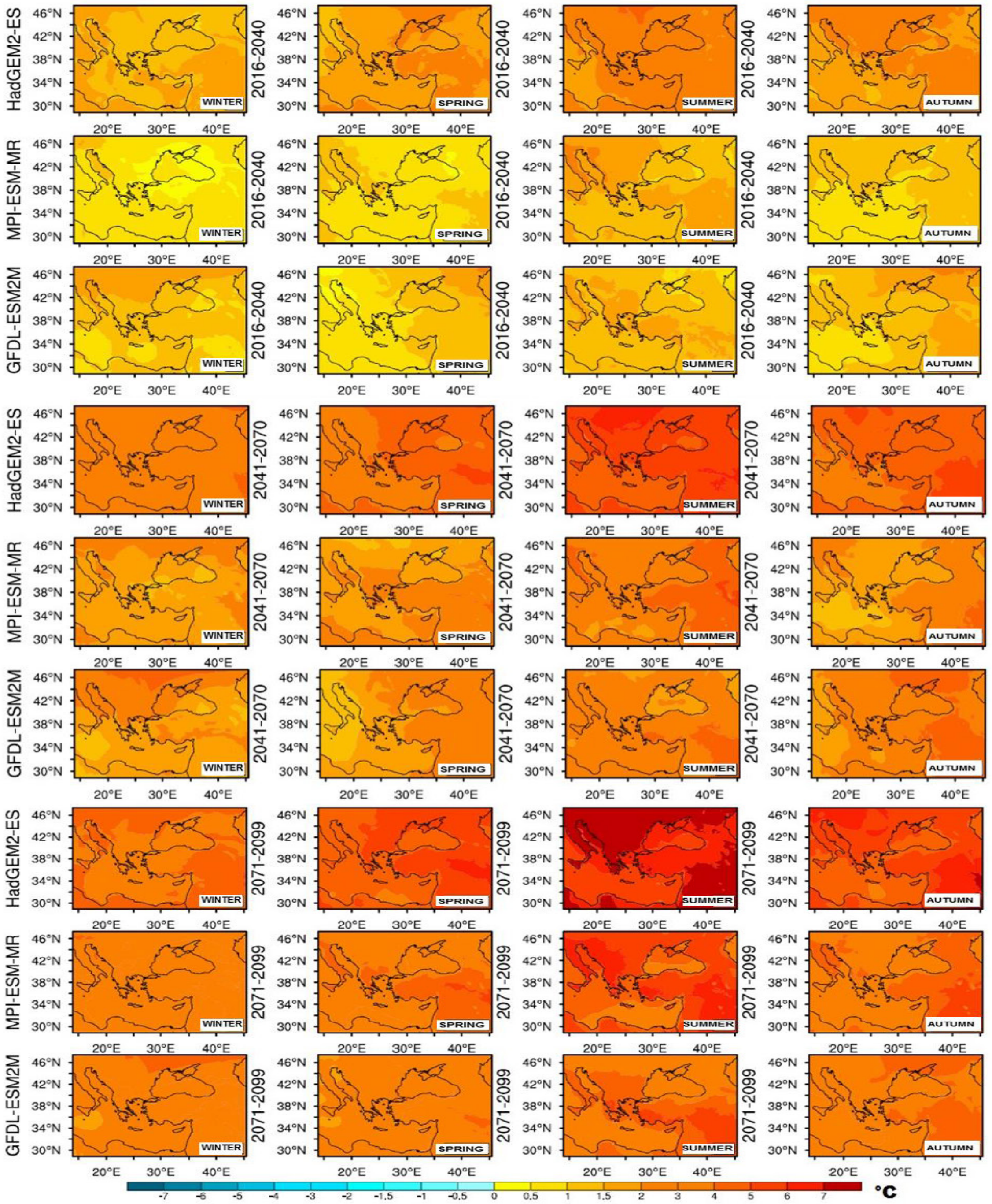

Figure 3.3. Temperature projections according to RCP8.5

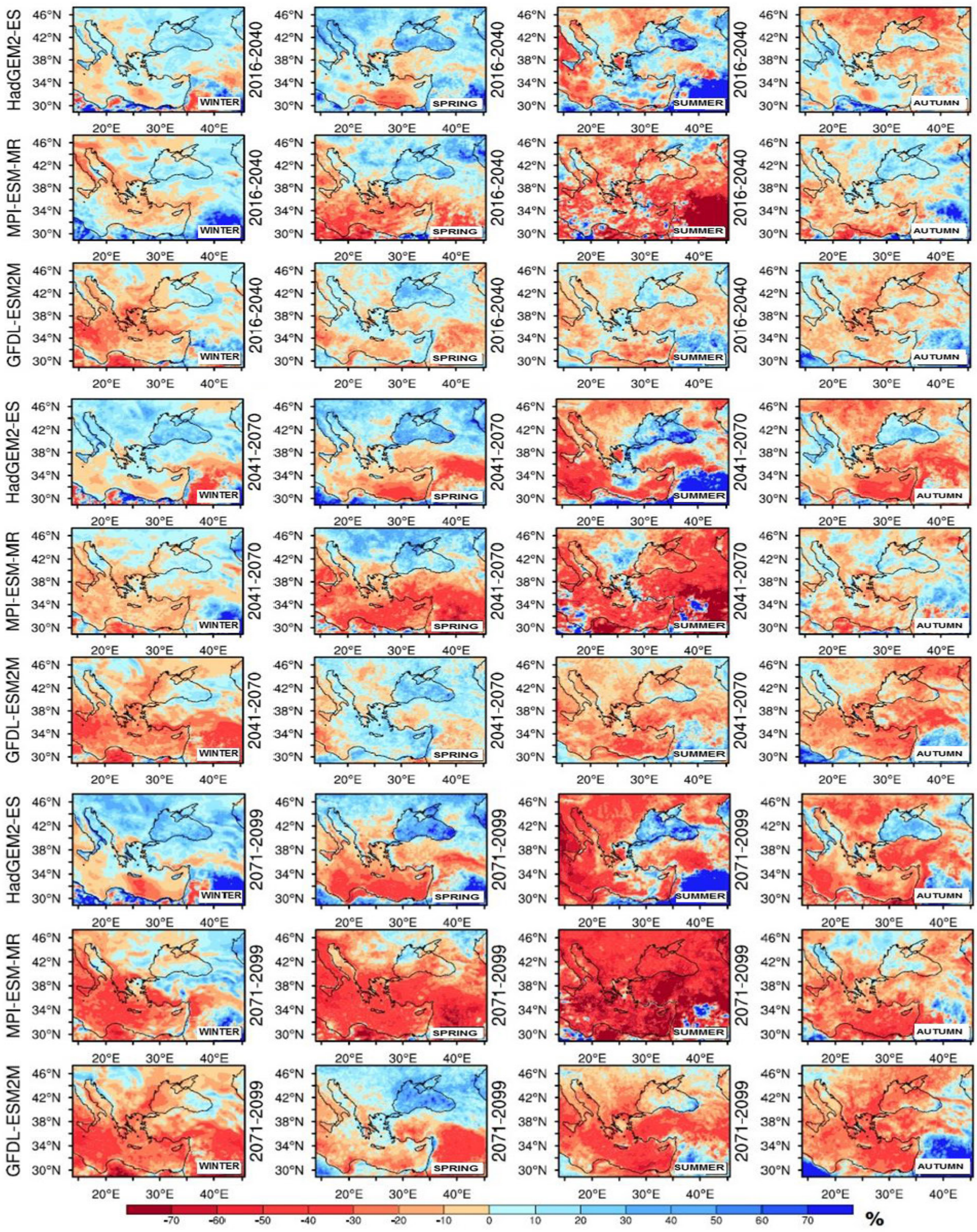

Figure 3.4. Precipitation projections according to RCP8.5

4. Discussion and Conclusion

"Climate Projections with New Scenarios for Turkey" is a project which is made by an official institution with its own resources, personnel, new models and scenarios for the first time in Turkey. In this context, RCP4.5 and RCP8.5 scenarios (2016-2099) of three different models data were downscaled in this project. Project studies are going on with different type climate products. According to obtained results based on through three GCMs (HadGEM2-ES, MPI-ESM-MR and GFDL-ESM2M) and two scenarios (RCP4.5 and RCP8.5), the average annual temperature rising for 2016-2040 in Turkey is expected to vary between 1°C - 2°C. In the period 2041–2070, the increase in the surface temperature is expected to vary between 1.5°C - 4°C. At the last period (2071-2099) the average annual temperature rising is expected to vary between 1.5°C - 5°C. In some scenarios, it is projected that the temperature increase would be reached to 3°C in winter and up to 6°C in summer in the last 30 years of the 21st century (2071–2099). The increase would be higher in winter for the eastern and inner parts of Turkey, while it would be higher in summer for south-eastern Turkey and the coastal regions except Black Sea Region.

Table 4.1.

Summarise table of temperature projections (Temperature anomaly (°C) ranges)

Models	Periods	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5
		Winter		Spring		Summer		Autumn	
HadGEM2-ES	2016-2040	1,5 - 2	0 - 1	2 - 3	1 - 2	2 - 3	1,5 - 2	2 - 3	1 - 2
	2041-2070	1,5 - 2	1,5 - 2	2 - 3	2 - 3	2 - 3	3 - 4	2 - 3	2 - 3
	2071-2099	2 - 3	2 - 3	2 - 3	3 - 5	3 - 4	5 - 7	3 - 4	4 - 6
MPI-ESM-MR	2016-2040	0 - 1	0 - 1	0 - 1,5	1 - 1,5	1 - 2	1,5 - 2	0 - 1,5	1 - 1,5
	2041-2070	1,5 - 2	1 - 2	1 - 2	2 - 3	1 - 2	2 - 4	1 - 2	1,5 - 2
	2071-2099	1 - 1,5	2 - 3	1,5 - 2	3 - 5	1,5 - 3	4 - 6	1 - 2	3 - 5
GFDL-ESM2M	2016-2040	0,5 - 1	0,5 - 1	0,5 - 1	0,5 - 1	0,5 - 1,5	1 - 2	0,5 - 1	1 - 1,5
	2041-2070	1 - 1,5	1,5 - 2	1 - 1,5	1,5 - 2	1,5 - 2	2 - 3	1 - 2	2 - 3
	2071-2099	0,5 - 1	1,5 - 2	1 - 1,5	2 - 4	1,5 - 3	3 - 5	1 - 2	3 - 4

Table 4.2.

Summarise table of precipitation projections (Rainfall change (%) ranges)

Models	Periods	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5
		Winter		Spring		Summer		Autumn	
HadGEM2-ES	2016-2040	-30, +40	-20, +30	-20, +40	-30, +30	-40, +40	-40, +50	-30, +30	-40, +40
	2041-2070	-20, +30	-30, +30	-30, +30	-40, +40	-60,+60	-60, +60	-40, +40	-40,+40
	2071-2099	-40, +40	-30, +40	-40, +40	-40, +40	-50, +50	-60, +60	-50, +40	-50, +40
MPI-ESM-MR	2016-2040	-30, +30	-30, +30	-40, +30	-40, +40	-50, +50	-60, +50	-40, +30	-40, +40
	2041-2070	-30, +30	-30, +30	-40, +40	-40, +30	-50, +50	-60, +50	-40, +30	-40, +40
	2071-2099	-30, +30	-40, +50	-40, +50	-50, +30	-70, +40	-60, +30	-40, +40	-40, +40
GFDL-ESM2M	2016-2040	-30, +20	-40, +40	-30, +30	-30, +20	-40, +30	-30, +40	-40, +20	-40, +30
	2041-2070	-40, +30	-40, +30	-40, +30	-30, +40	-40, +50	-40, +30	-40, +20	-40, +20
	2071-2099	-30, +30	-40, +40	-30, +30	-40, +40	-40, +40	-50, +30	-40, +30	-40, +40

In context of climate change, serious risks in river basins of Turkey is foreseen to occur due to possible new climate conditions in the future. One of these issues is the trend of decreasing in the amount of rainfall throughout Turkey particularly in the southern and inner parts of Anatolia and especially in Tigris–Euphrates Basin. The second issue is increasing in temperature especially in winter season. The increase in temperature may cause to turn the precipitation type from snow to rain during the winter. Snow is important water source which is supplying water along to year. And also temperature increases could be cause early snow melting in spring. Bozkurt et. al. (2013) and Bozkurt et. al. (2015) also concluded early melting of snow and the temporal shifts in snowmelt runoff in the Euphrates-Tigris Basin. The third issue is increasing in amount of precipitation in west and north coastal part of Anatolia in summer season. This increase could be caused extreme precipitation events in mentioned regions. It is also concluded that in TECCWRP (2016) possibilities of occurring extreme precipitation and floods could be increased in Marmara and Black Sea regions in period of 2015-2100. This extreme precipitation could be cause to flood as seen as in recent years. And also increasing in temperature could be cause to increase the number and severity of extreme weather events such as storm, hail and waterspout. There have been an increasing trend in Turkey's observed temperature and similarly in extreme weather events number since 1997. SCT2015 reported that heavy rain/floods (26%), wind storm (25%), hail (12%), heat wave (11%), and lightning (4%) were recorded as the most observed disaster respectively in 2015. Although rare, 2 dust storm and 4 tornados also occurred in 2015.

Climate change prediction studies provides the main data input to sectors to make plans for adaptation, mitigation and prevention efforts against climate change issue. Under climate change context, high resolution data sets of GCM's is important to prepare a realistic adaptation plan in sectors. Using of these data will contribute to improve the accuracy and success of sectoral planning in adaptation, mitigation and prevention activities.

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Extended Turkish Abstract (Genişletilmiş Türkçe Özet)

Türkiye için İklim Değişikliği Projeksiyonları: Üç Model ve İki Senaryo

Senaryo, geleceğin hayali olarak canlandırılması veya alternatif gelecek durumların tasvir edilmesidir. Buna rağmen senaryo, tahmin ile karıştırılmaktadır. Senaryo geleceğin tahmini değil, olması muhtemel alternatif durumların ortaya konmasıdır. Senaryolar, iklim gibi yüksek belirsizliğe sahip karmaşık sistemlerin gelecekteki muhtemel gelişiminin anlaşılması ve değerlendirilmesinde önemli bir rol oynamaktadır. Bunu bize sağlayan ise model çalışmaları ve bu çalışmalar sonucunda elde edilen iklim projeksiyonlarıdır. Bu çalışmada, ülkemizi de içine alan bölgede, bölgesel iklim modeli çalışması ile geleceğe ait iklim değişikliği olasılıkları ortaya konmaya çalışılmıştır. Temsili Konsantrasyon Yolları (RCPs) adı, esas amaçları atmosferik Sera Gazları (GHG) konsantrasyonlarının zaman bağımlı projeksiyonları sağladığını vurgulayan rotalar olmasını temsil etmektedir. Bu çalışmada, Türkiye'yi içine alan bir bölge için gelecekteki iklim değişikliğinin muhtemel sonuçları ortaya konmaya çalışılmıştır. HadGEM2-ES,

MPI-ESM-MR ve GFDL-ESM2M Küresel Dolaşım Modellerinin RCP4.5 ve RCP8.5 senaryolarının sonuçları kullanılmıştır. Bu çıktılardan, Türkiye için sıcaklık ve yağış projeksiyonları; RegCM4.3.4 bölgesel iklim modeli ile dinamik ölçek küçültme yöntemi kullanılarak, 20 km çözünürlükte ve 2016-2099 yıllarını kapsayan bir dönem için üretilmiştir.

İklimin insan hayatındaki önemi, iklimin sosyal ve ekonomik hayatı olumlu ya da olumsuz etkileri ile nasıl etkilediği ile ilgilidir. İnsanların daha iyi koşullar altında, daha sağlıklı bir şekilde yaşamlarını sürdürebilmeleri için, gerek ulusal gerekse uluslararası birçok kurum ve kuruluş, organizasyon, merkezi ve yerel yönetimler ile sivil toplum örgütleri iklimde meydana gelebilecek değişimler ve bu değişimlerin etkilerinin doğru saptanabilmesi için farklı şekillerde çaba sarf etmektedirler.

Bu çabalardan en önemlisi modelleme çalışmalarıdır. Teknolojinin gelişmesi ile birlikte ortam koşullarını ifade eden değişkenler, daha detaylı bir şekilde modellerde yer alabilmektedir. 1970'li yıllardan itibaren bilgisayarların bilimsel amaçlı kullanımlarının yaygınlaşması ile iklim modelleri de kullanılmaya başlamıştır. Çalışılan ilk modellerde sadece atmosfer ve atmosferde gözlenen parametrelere göre çalışmalar yapılmış olup gelişmelere paralel olarak kara yüzeyi, okyanuslar, deniz buzları, sülfat, aerosoller, karbon çevrimi, dinamik bitki örtüsü ve atmosferin kimyası gibi etmenler modellere girdi teşkil eden parametreler olmuştur.

Teknolojinin gelişimi ile daha da küçülen Dünyamızda iklim değişikliği hakkında yapılan çalışmalar, 1990'lı yılardan sonra IPCC (Uluslararası İklim değişikliği Paneli) adı altında oluşturulan birliktelik ve oluşumun yönlendirmeleri ile daha anlamlı bir çaba içine girmiştir. Oluşan bu birlikteliğin çalışma sonuçları belli dönemlerle gerçekleştirilmiştir. IPCC'de yüzlerce bilim adamının katkıda bulunduğu en son 4. Değerlendirme Raporu'nda, önce 40 farklı senaryo gözden geçirilmiş ve bunların içinden 7 senaryo belirlenmiştir. İklim modelleri ayrıntılı bir şekilde ortam şartlarını, beklenen değişimlere göre yeniden kurgulama imkânı vermektedir. Bu bağlamda, 2007'de yayınlanan IPCC'nin 4. Değerlendirme Raporu'ndan bu tarafa, değişen arazi kullanımı/değişimi, sera gazı emisyonları ve konsantrasyonları, aerosol konsantrasyonu bilgileri ile gelişen teknolojik altyapı ve modelleme teknikleri yeni bir değerlendirme raporu hazırlanması ihtiyacını ortaya çıkarmıştır. Bu kapsamda IPCC yeni senaryolar ile 5. Değerlendirme Raporunu hazırlamış ve dünya gündemine sunmuştur.

İklim, geniş zaman dilimlerinde ve daha büyük alanlarda tecrübe edilmiş ortalama hava durumudur. İklim normalleri iklim verilerinden hesaplanan ardışık otuz yılın ortalamasıdır. İklim normallerini kullanmak küresel değerlendirme ve iklim izleme çalışmalarını hazırlamak için standart temel oluşturan çok önemli araçlardır. İklim referans dönemleri; 1961-1990, 1971-2000 ve 1981-2010 iklim normalleri olarak; uluslararası, ulusal ve bölgesel temelli iklim izleme, iklim trendi iklim değişikliği ve iklim modeli çalışmalarında; bilim adamları, ulusal iklim servisleri, uluslararası enstitüler ve organizasyonlar tarafından kullanılmaktadır.

"Türkiye için İklim Değişikliği Projeksiyonları" projesi Türkiye'de ilk kez yeni model ve senaryolar ile bir kamu kurumu tarafından kendi kaynakları ve personeli kullanılarak yapılmıştır. Bu bağlamda, üç farklı küresel modelin RCP4.5 ve RCP8.5 senaryolarının (2016-2099) ölçek küçültme çalışmaları yapılmıştır. Proje çalışmaları farklı iklim ürünleri çalışmaları ile devam etmektedir. Üç Küresel Dolaşım Modeli (GCMs; HadGEM2-ES, MPI-ESM-MR ve GFDL-ESM2M) ve iki senaryodan (RCP4.5 ve RCP8.5) elde edilen sonuçlara göre Türkiye'de yıllık ortalama sıcaklık artışının; 2016-2040 dönemi için 1°C - 2°C arasında; 2041–2070 dönemi için 1.5°C - 4°C arasında ve son dönem olan 2071-2099 dönemi 1.5°C - 5°C arasında olması öngörülmektedir. Bazı senaryolarda 21 yy. son otuz yılında (2071–2100) sıcaklık artışının kış mevsiminde 3°C ve yaz mevsiminde 8°C'ye ulaşması da öngörülmektedir. Yağışlarda; tüm dönemlerde kış mevsimi için ülke genelinde yağış miktarında artışlar, ilkbahar mevsiminde tüm dönemlerde ülkenin sahil ve kuzeydoğu kesimleri haricinde yağış miktarında azalışlar, yaz mevsiminde tüm dönemlerde ülkenin batı sahilleri ve kuzeydoğu bölümleri haricinde yağış miktarında azalışlar ve sonbahar mevsiminde genel olarak yağış miktarında bir azalma öngörülmektedir. Her ne kadar projeksiyon dönemi boyunca (2016-2099) yağış miktarında düzenli bir artış ve azalış eğilimi olmasa da, yağış rejiminin düzensizliği dikkat çekicidir.

İklim değişikliği bağlamında, yeni iklim şartlarında Türkiye nehir havzalarında ciddi risklerin oluşması öngörülmektedir. Bunlardan bir tanesi, özellikle Fırat-Dicle havzası olmak üzere, Anadolu'nun iç kesimleri ve güneyindeki havzalarda yağış miktarındaki azalıştır. İkincisi ise artan sıcaklıkların yağış cinsi değişikliklerine neden olması ve kış mevsimindeki yağan karın yağmura dönüşmesidir. Kar yıl boyunca su sağlayan önemli bir kaynaktır. Ayrıca artan sıcaklıklar karın baharda erken erimesine neden olacaktır. Üçüncü sorun ise, özellikle yaz mevsiminde ve özellikle Anadolu'nun batı ve kuzey sahil kesimlerinde aşırı yağışların oluşma riskidir. Bu aşırı yağışlar son yıllarda olduğu gibi sellere neden olabileceklerdir. Ayrıca artan sıcaklıklar; fırtına, dolu ve hortum gibi aşırı hava olaylarının sayısında ve şiddetinde artışa yol açabilecektir.

İklim değişikliği öngörü çalışmaları bütün sektörlere uyum, önleme ve azaltma çabalarında yani paydaşların gelecek planlarında -ki bunlar iklim ve iklim model çıktıları temelli yapılmalıdır- esas veri ve temel altlığı sağlamaktadır. İklim değişikliği çalışmaları kapsamında farklı iklim modellerinin senaryoları, Türkiye ve çevresi için ölçek küçültme yöntemi ile üretilmelidir. Böylelikle gelecekte muhtemel olması öngörülen iklim değişikliği ihtimallerini daha detaylı görmek mümkün olacaktır. Yüksek çözünürlüklü iklim model projeksiyonları erişilebilir olduğunda ve sektörler bu verileri uyum, önleme ve azaltma planlarında kullandıklarında, çalışmalarının doğruluğu ve başarısı da artacaktır.