Vol-2, Issue-6 PP. 1009-1019 ISSN: 2394-5788

GLOBAL JOURNAL OF ADVANCED RESEARCH
(Scholarly Peer Review Publishing System)

ROBUST STATISTICAL PROCEDURE TO DETERMINE SUITABLE SCENARIO OF SOME CMIP5 MODELS FOR FOUR LOCATIONS IN EGYPT

Tarek Sayad
Astronomy and Meteorology Department,
Faculty of Science, Al Azhar University 11884, Cairo,
Egypt.

Samiha Ouda
Water Requirements and Field Irrigation Research
Department; Soils, Water and Environment Research
Institute; Agricultural Research Center 12619, Giza,
Egypt.

Mostafa Morsy
Astronomy and Meteorology Department,
Faculty of Science, Al Azhar University 11884, Cairo,
Egypt.

Fathy El Hussieny
Astronomy and Meteorology Department,
Faculty of Science, Al Azhar University 11884, Cairo,
Egypt.

ABSTRACT

The objectives of this research were (i) to compare between measured weather data and projected data (2006-2014) from four global climate models (BCC-CSM1-1, CCSM4, GFDL-ESM2G and MIROC5), with four Representative Concentration Pathways (RCPs) scenarios (RCP2.6, RCP4.5, RCP6.0 and RCP8.5) developed for four Egyptian governorates (Kafr El-Sheikh, El-Gharbia, El-Minya and Sohag); (ii) to determine the suitable RCPs climate change scenarios at each governorate. Weather data was compared to projected data by the selected scenarios of the selected models. Goodness of fit measurements for some statistical parameters between measured and projected data were calculated. The results indicated that the RCP6.0 developed by CCSM4 model and RCP8.5 developed by BCC-CSM1-1 and MIROC5 models were acceptable for Kafr El-Sheikh governorate. Whereas, the suitable scenarios for El-Gharbia governorate was RCP6.0 developed by CCSM4 model and RCP8.5 developed by MIROC5 model. Nevertheless, in El-Minia governorate, the highest agreement between measured and projected values was found for RCP8.5 and RCP6.0 scenarios developed by CCSM4 model. With respect to Sohage, the most suitable scenario was RCP6.0 which is developed by CCSM4 model. Consequently, it is recommended to prefer using the RCP6.0 scenario developed by CCSM4 model as a suitable scenario for all selected governorates. The statistical procedure used in this paper can be used by other researchers around the world, especially in developing countries to reduce uncertainty in simulation of climate change risks on agriculture and water resources.

Keywords: Some of CMIP5 models; RCPs scenarios; Goodness of fit parameters.

1. INTRODUCTION

Global and regional climates have already begun changing, probably from accumulating emissions of anthropogenic greenhouse gases (Daniel et al. 2007). The models that describe global climate are mathematical representations of physical and dynamical processes to simulate the interaction within and in between the atmosphere, land surface, oceans and sea ice. The climate projections in the Intergovernmental Panel on Climate Change fourth assessment report (AR4) were based on the IPCC Special Report on Emissions Scenarios (SRES) (IPCC 2007), which simulate the third phase of the Coupled Model Inter-comparison Project3 (CMIP3) (Joeri et al. 2012). Whereas, new global climate change models for new projection, mitigation and adaptation scenarios involving policy decisions and options for targeted climate change stabilization at different levels were developed during the IPCC Fifth Assessment Report (AR5) (IPCC 2013). Its findings were based on a new set of scenarios that replace SRES (Wayne 2013). The climate projections in the IPCC fifth assessment report were based on Coupled Model Inter-comparison Project Phase 5 (CMIP5). This presents an unprecedented level of information on which to base projections including the latest versions of climate models. It includes more complete representation of forcings to produce a new four Representative Concentration Pathways scenarios (RCPs) and more output available for analysis.

Taylor et al. (2012) stated that the simulations of a new generation of state-of-the-art global climate models (GCM) are becoming available for analysis in the time line of the AR5 of the IPCC. The efforts for CMIP5 are enormous, with a larger number of more complex models run at higher resolution, with more complete representations of external forcings, more types of scenario and more diagnostics stored (Knutti and Sedlacek 2012). There are more comprehensive global climate models including in CMIP5 comparing with CMIP3 that have a generally higher spatial resolution, which enabling the research communities to address a wider variety of scientific questions (Meehl et al. 2007). The main improvements in CMIP5 includes addition of interactive ocean and land carbon cycles of varying degrees of complexity, more comprehensive modeling of the indirect effect of aerosols and the use of time-evolving volcanic and solar forcing in most models (e.g., Taylor et al. 2012).

Uncertainty in future climate change presents a key challenge for adaptation planning. Uncertainty in climate information form limitations in our ability to model climate system and in our understanding of how future greenhouse gas emissions will change (Cox and Stephenson 2007). In general, we can have greater confidence in projections for larger regions than for specific locations and in temperature projections than those for precipitation (Moss et al. 2010). However, according to (IPCC, 2013), the goal of working with RCPs scenarios is not only future climate projection, but also better understanding of uncertainties. Projected climate change based on RCPs is similar to AR4 in both patterns and magnitude, after accounting for scenario differences. The overall spread of projections for the high RCPs is narrower than comparable scenarios used in AR4, because the RCPs used in AR5 are defined as concentration pathways (IPCC 2013). Gagnon-Lebrun and Agrawala (2006) noted that the level of certainty associated with climate change and impact projections is a key to determining the extent to which such information can be used to formulate appropriate adaptation responses. While, the information on changes in climate extremes of the CMIP5 can provide important data for impact studies and the simulations ensemble is the best available source for climate change projections (Klein Tank et al. 2009). Thus, it is very desirable to evaluate the performance of climate model under past and current climate conditions because scientific understandings of phenomena are often tested via predictions that are compared against observations. Thus, to give recommendation on which of AR5 model scenario is suitable to be use locally, robust statistical comparison should be employed to reduce uncertainty and increase reliability.

Thus, the primary purposes and objectives of this research were (i) to compare between measured weather data and projected data (2006-2014) from four global climate models (BCC-CSM1-1, CCSM4, GFDL-ESM2G and MIROC5), with four RCPs scenarios (RCP2.6, RCP4.5, RCP6.0 and RCP8.5) developed for four Egyptian governorates (Kafr El-Sheikh, El-Gharbia, El-Minya and Sohag); (ii) to determine the suitable RCP climate change scenarios at each governorate and consequently aver all Egypt.

GLOBAL JOURNAL OF ADVANCED RESEARCH
(Scholarly Peer Review Publishing System)

2. MATERIAL AND METHODS

2.1 Selected Sites and Weather Data

Four governorates were selected, i.e. Kafr El-Sheikh (North Nile Delta, latitude 31.08º N, longitude 30.94º E and elevation 20 m), El-Gharbia (Middle Nile Delta, latitude 30.78º N, longitude 31.12º E and elevation 15 m), El-Minya (Middle Egypt, latitude 27.73º N, longitude 30.84º E and elevation 40 m) and Sohag (Upper Egypt, latitude 26.60º N, longitude 31.65º E and elevation 69 m).

Daily weather data for these four governorates were collected for nine years from 2006 to 2014. Four weather elements were obtained, i.e. solar radiation (MJ/m^2/day), as well as maximum, minimum and mean temperatures (ºC).

2.2 Climate Change Models

The selection of models in this study was designed to include models with differing levels of sensitivity to Green House Gases (GHG) forcing. These models focused on daily RCPs climate change scenarios with different resolutions. A list of the selected models is shown in Table (1).

Table 1. List of used CMIP5 GCMs models and their horizontal resolutions.

Model	Institution	Horizontal resolution
BCC-CSM1-1	Beijing Climate Center, China Meteorological Administration, China.	2.80º x 2.80º
CCSM4	National Centre for Atmospheric Research (NCAR), Community Climate System Model, USA.	1.25º x 0.94º
GFDL-ESM2G	National Oceanic and Atmospheric Administration (NOAA), Geophysical Fluid Dynamics Laboratory (GFDL), USA.	2.5 º x 2.0º
MIROC5	Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology, Japan.	1.4 º x 1.4 º

The CMIP5 GCMs outputs provide four RCPs; these scenarios are RCP2.6, RCP4.5, RCP6.0 and RCP8.5, where the numbers refer to forcings for each RCP. The radiative forcing is a measure of the influence a factor has in altering the balance of incoming and outgoing energy in the Earth-atmosphere system, measured in watts per square meter. The scenarios can be described as following:

RCP2.6: It is also called RCP3-PD and PD stands for Peak and Decline. The emission pathway is representative of scenarios in the literature that lead to very low greenhouse gas concentration levels. It is a "peak-and-decline" scenario; its radiative forcing level first reaches a value of around 3.1 W/m^2 by mid-century, and returns to 2.6 W/m^2 by 2100. In order to reach such radiative forcing levels, greenhouse gas emissions (and indirectly emissions of air pollutants) are reduced substantially over time (Van Vuuren et al. 2007; Van Vuuren et al. 2006).

RCP4.5: It is a stabilization scenario in which total radiative forcing is stabilized shortly after 2100, without overshooting the long-run radiative forcing target level (Clarke et al. 2007; Smith and Wigley 2006; Wise et al. 2009).

RCP6.0: It is a stabilization scenario in which total radiative forcing is stabilized shortly after 2100, without overshoot, by the application of a range of technologies and strategies for reducing greenhouse gas emissions (Fujino et al. 2006; Hijioka et al. 2008).

RCP8.5: This RCP is characterized by increasing greenhouse gas emissions over time, representative of scenarios in the literature that lead to high greenhouse gas concentration levels (Riahi et al. 2007).

Each RCP defines a specific emissions trajectory and subsequent radiative forcing as shown in Table (2).

GLOBAL JOURNAL OF ADVANCED RESEARCH
(Scholarly Peer Review Publishing System)

Table 2. Median temperature anomaly over pre-industrial levels and SRES comparisons based on nearest temperature anomaly.

Name	Radiative forcing	CO2 equivalent (ppm)	Temperature anomaly (°C)	Pathway	SRES temperature anomaly equivalent
RCP2.6	3.0 W/m^2 before 2100, declining to 2.6 W/m^2 by 2100	490	1.5	Peak and decline	None
RCP4.5	4.5 W/m^2 post 2100	650	2.4	Stabilization without overshoot	SRES B1
RCP6.0	6.0 W/m^2 post 2100	850	3	Stabilization without overshoot	SRES B2
RCP8.5	8.5 W/m^2 in 2100	1370	4.9	Rising	SRES A1F1

Source: Rogelj et al. 2012

2.3 Comparison Procedure

One way to evaluate climate models is to compare variables from model outputs with the observed data over past and present periods. For this, the daily measured data in the four studied governorates during the period from 2006 to 2014 were compared to the daily projected climate data from the used four models, each represented by four RCPs scenarios. The period 2006-2014 is also often used as a reference when looking at climate changes projections in the future after year of 2014. The goodness of fit between the measured and projected data was examined by calculating the following measurements:

2.3.1 Willmott index of agreement (d)

It is the standardized measure of the degree of model prediction error and varies between 0 and 1. A value of 1 indicates a perfect match, and value of 0 indicates no agreement at all (Willmott 1981).

$$d = 1 - \frac{\sum_{i=1}^{n}(O_i - S_i)^2}{\sum_{i=1}^{n}[(|(S_i - \bar{O})| + |(O_i - \bar{O})|)^2]} \qquad (1)$$

Where O_i, $\bar{O}$ and S_i represent the observed, observed average and simulated values.

2.3.2 Coefficient of Determination (R^2)

R^2 tells us how much better we can do in predicting observation by using the model and computing the simulation by just using the mean observation as a predictor (Jamieson et al. 1998).

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(O_i - S_i)^2}{\sum_{i=1}^{n}(O_i - \bar{O})^2} \qquad (2)$$

R^2 ranges from 0 to 1, with higher values indicating less error variance, and typically values greater than 0.5 are considered acceptable (Santhi et al. 2001; Van Liew et al. 2003; Moriasi et al. 2007).

2.3.3 Root Mean Square Error per Observation

It gave the general standard deviation of the model prediction error and per observation (Jamieson et al. 1998).

$$RMSE/obs = \frac{\sqrt{\sum_{i=1}^{n}(S_i - O_i)^2/n}}{\bar{O}} \qquad (3)$$

Where, n represents the number of observed and simulated values used in comparison.

GLOBAL JOURNAL OF ADVANCED RESEARCH
(Scholarly Peer Review Publishing System)

2.3.4 Mean Bias Error per Observation

It is a measure of overall bias error or systematic error between the observed and the simulated parameters (Singh et al. 2013).

$$\mathrm{MBE/obs} = \frac{\sum_{i=1}^{n}(S_i - O_i)/n}{\bar{O}} \quad (4)$$

For all selected weather elements, the RCP scenarios with the highest closeness between measured and projected values in the four models was used to determine the best RCP climate change scenario obtained from the selected four models. This closeness implied that the scenario is suitable to study climate change effects on agriculture and/or hydrology in the selected governorates.

3. RESULTS AND DISCUSSION

3.1 Kafr El-Sheikh Governorate

Regarding to Kafr El-Sheikh governorate, the closest values of projected solar radiation and minimum temperature to measured values were obtained from BCC-CSM1-1 model. Whereas, the closest values of projected maximum and mean temperature to measured values were obtained from CCSM4 and MIROC5 models, respectively (Table 3). This trend was true for RCP2.6, RCP4.5 and RCP6.0. Regarding to RCP8.5, the projected values of minimum temperature by BCC-CSM1-1 model was close to the measured values. Furthermore, the projected values by CCSM4 model for solar radiation and maximum temperature were close to the measured values. The measured mean temperature was close to the projected values by MIROC5 model (Table 3).

But, goodness of fit test revealed that the highest closeness between measured and projected scenarios was found for RCP6.0 developed by CCSM4 model. Furthermore, RCP8.5 developed by BCC-CSM1-1 or by MIROC5 models was also acceptable (Table 4).

Table 3. Average measured and projected data for the selected models with all RCPs scenarios during the period from 2006 to 2014 at Kafr El-Sheikh Governorate.

Kafr El-Sheikh	BCC-CSM1-1 Model	CCSM4 Model	GFDL Model	MIROC5 Model	Measured
Rad-RCP2.6	20.86	21.09	21.08	21.19	20.45
Tmax-RCP2.6	23.27	27.31	23.70	24.73	26.60
Tmin-RCP2.6	18.51	19.21	18.70	19.57	18.49
Tmean-RCP2.6	20.90	23.09	21.26	21.94	21.87
Rad-RCP4.5	20.86	21.09	21.10	21.24	20.45
Tmax-RCP4.5	23.40	27.17	23.76	24.62	26.60
Tmin-RCP4.5	18.66	19.06	18.84	19.47	18.49
Tmean-RCP4.5	21.02	22.94	21.36	21.84	21.87
Rad-RCP6.0	21.02	21.15	21.29	21.26	20.45
Tmax-RCP6.0	23.40	27.09	23.61	24.69	26.60
Tmin-RCP6.0	18.65	19.00	18.70	19.57	18.49
Tmean-RCP6.0	21.03	22.87	21.21	21.92	21.87
Rad-RCP8.5	21.04	21.01	21.14	21.30	20.45
Tmax-RCP8.5	23.41	27.17	23.60	24.56	26.60
Tmin-RCP8.5	18.60	19.14	18.66	19.44	18.49
Tmean-RCP8.5	21.01	22.98	21.19	21.79	21.87

Rad = Solar radiation, Tmax = Maximum temperature, Tmin = Minimum temperature and Tmean = Mean temperature

GLOBAL JOURNAL OF ADVANCED RESEARCH
(Scholarly Peer Review Publishing System)

Table 4. Goodness of fit parameters between measured and projected weather data by the four models at Kafr El-Sheikh governorate.

Kafr El-Sheikh	BCC-CSM1-1 model				CCSM4 model			
	d	R^2	RMSE/obs	MBE/obs	d	R^2	RMSE/obs	MBE/obs
RCP2.6	0.884	0.684	0.183	-0.037	0.898	0.700	0.176	0.038
RCP4.5	0.891	0.703	0.173	-0.033	0.896	0.686	0.175	0.033
RCP6.0	0.893	0.709	0.173	-0.031	0.903	0.706	0.170	0.031
RCP8.5	0.894	0.713	0.173	-0.031	0.894	0.686	0.177	0.034
	GFDL model				MIROC5 model			
	d	R^2	RMSE/obs	MBE/obs	d	R^2	RMSE/obs	MBE/obs
RCP2.6	0.875	0.649	0.196	-0.024	0.891	0.685	0.167	0.007
RCP4.5	0.874	0.646	0.197	-0.020	0.893	0.690	0.166	0.004
RCP6.0	0.869	0.642	0.204	-0.023	0.894	0.691	0.166	0.007
RCP8.5	0.877	0.662	0.196	-0.025	0.896	0.698	0.164	0.003

3.2 El-Gharbia Governorate

Similar trend was observed in El-Gharbia governorate, where the closest values of projected solar radiation and minimum temperature to measured values were obtained from BCC-CSM1-1 model. Whereas, the closest values of projected maximum and mean temperature to measured values were obtained from CCSM4 and MIROC5 models, respectively. This trend was true for RCP2.6, RCP4.5 and RCP6.0, in addition to RCP8.5 (Table 5).

However, the results in Table (6) revealed that there were good agreements between measured and projected values by RCP6.0 scenario developed by CCSM4 model and RCP8.5 developed by MIROC5 model.

Table 5. Average measured and projected data for the selected models during the period from 2006 to 2014 at El-Gharbia governorate.

El-Gharbia	BCC-CSM1-1 Model	CCSM4 Model	GFDL Model	MIROC5 Model	Measured
Rad-RCP2.6	21.01	21.41	21.25	21.52	20.73
Tmax-RCP2.6	24.10	29.21	24.29	26.19	30.82
Tmin-RCP2.6	18.10	18.95	18.42	19.01	15.78
Tmean-RCP2.6	21.11	23.90	21.46	22.32	22.46
Rad-RCP4.5	20.98	21.41	21.27	21.58	20.73
Tmax-RCP4.5	24.26	29.07	24.35	26.06	30.82
Tmin-RCP4.5	18.28	18.79	18.55	18.91	15.78
Tmean-RCP4.5	21.27	23.75	21.54	22.22	22.46
Rad-RCP6.0	21.16	21.46	21.47	21.57	20.73
Tmax-RCP6.0	24.27	28.98	24.21	26.12	30.82
Tmin-RCP6.0	18.28	18.73	18.40	18.99	15.78
Tmean-RCP6.0	21.28	23.67	21.40	22.28	22.46
Rad-RCP8.5	21.17	21.35	21.33	21.61	20.73
Tmax-RCP8.5	24.27	29.06	24.19	26.01	30.82
Tmin-RCP8.5	18.20	18.88	18.36	18.89	15.78
Tmean-RCP8.5	21.24	23.79	21.37	22.17	22.46

GLOBAL JOURNAL OF ADVANCED RESEARCH
(Scholarly Peer Review Publishing System)

Table 6. Goodness of fit parameters between measured and projected weather data by the four models at El-Gharbia governorate.

El-Gharbia	BCC-CSM1-1 Model				CCSM4 Model			
	d	R^2	RMSE/obs	MBE/obs	d	R^2	RMSE/obs	MBE/obs
RCP2.6	0.845	0.667	0.232	-0.029	0.886	0.700	0.211	0.061
RCP4.5	0.845	0.683	0.227	-0.024	0.882	0.685	0.211	0.056
RCP6.0	0.849	0.688	0.227	-0.021	0.888	0.702	0.206	0.054
RCP8.5	0.852	0.692	0.225	-0.023	0.883	0.691	0.211	0.057
	GFDL Model				MIROC5 Model			
	d	R^2	RMSE/obs	MBE/obs	d	R^2	RMSE/obs	MBE/obs
RCP2.6	0.844	0.653	0.238	-0.016	0.840	0.657	0.227	0.021
RCP4.5	0.845	0.657	0.238	-0.012	0.845	0.668	0.225	0.018
RCP6.0	0.846	0.655	0.241	-0.015	0.845	0.670	0.225	0.021
RCP8.5	0.849	0.668	0.236	-0.018	0.846	0.673	0.223	0.018

3.3 El-Minia Governorate

Different trend were obtained in El-Minia governorate, where the closest projected solar radiation to measured values were obtained from GFDL model for the four scenarios. Whereas, the closest projected minimum temperature to measured value were obtained from MIROC5 model for PCR4.5 and RCP6.0. Regarding to RCP2.6 and RCP8.5 the closest projected minimum temperature to measured value were obtained from CCSM4 model. Furthermore, the closest values between projected and measured maximum and mean temperature were obtained from BCC-CSM1-1 model for RCP6.0 scenario as indicated in Table (7).

Table 7. Average measured and projected data for the selected models with all RCPs scenarios during the period from 2006 to 2014 at El-Minia Governorate.

El-Minia	BCC-CSM1-1 Model	CCSM4 Model	GFDL Model	MIROC5 Model	Measured
Rad-RCP2.6	21.62	22.87	22.36	23.42	22.46
Tmax-RCP2.6	29.41	29.21	27.51	32.46	30.98
Tmin-RCP2.6	16.99	16.54	15.99	16.75	16.57
Tmean-RCP2.6	23.14	22.83	22.05	24.67	23.24
Rad-RCP4.5	21.47	22.92	22.42	23.57	22.46
Tmax-RCP4.5	29.76	29.33	27.54	32.28	30.98
Tmin-RCP4.5	17.43	16.47	16.06	16.60	16.57
Tmean-RCP4.5	23.51	22.85	22.10	24.51	23.24
Rad-RCP6.0	21.70	22.91	22.67	23.32	22.46
Tmax-RCP6.0	29.78	28.98	27.47	32.30	30.98
Tmin-RCP6.0	17.41	16.45	15.94	16.67	16.57
Tmean-RCP6.0	23.53	22.66	22.00	24.54	23.24
Rad-RCP8.5	21.65	22.84	22.61	23.46	22.46
Tmax-RCP8.5	29.71	29.18	27.50	32.31	30.98
Tmin-RCP8.5	17.15	16.65	15.81	16.67	16.57
Tmean-RCP8.5	23.36	22.87	21.94	24.56	23.24

GLOBAL JOURNAL OF ADVANCED RESEARCH
(Scholarly Peer Review Publishing System)

Nevertheless, in El-Minia governorate, the highest agreement between measured and projected values was found for RCP8.5 scenario developed by CCSM4 model only (Table 8).

Table 8. Goodness of fit parameters between measured and projected weather data by the four models at El-Minia governorate.

El-Minia	BCC-CSM1-1 Model				CCSM4 Model			
	d	R^2	RMSE/obs	MBE/obs	d	R^2	RMSE/obs	MBE/obs
RCP2.6	0.860	0.604	0.222	-0.017	0.879	0.659	0.204	-0.015
RCP4.5	0.865	0.618	0.213	-0.005	0.877	0.653	0.203	-0.014
RCP6.0	0.866	0.617	0.214	-0.002	0.880	0.662	0.201	-0.019
RCP8.5	0.866	0.621	0.216	-0.009	0.881	0.667	0.199	-0.013
	GFDL Model				MIROC5 Model			
	d	R^2	RMSE/obs	MBE/obs	d	R^2	RMSE/obs	MBE/obs
RCP2.6	0.853	0.604	0.226	-0.051	0.873	0.634	0.211	0.041
RCP4.5	0.856	0.615	0.223	-0.048	0.877	0.645	0.207	0.037
RCP6.0	0.858	0.621	0.227	-0.049	0.876	0.642	0.208	0.036
RCP8.5	0.862	0.635	0.220	-0.052	0.878	0.649	0.207	0.038

3.4 Sohag Governorate

With respect to Sohag governorate, no model/scenario achieved a trend similar to the other governorates (Table 9). Each model/scenario projected values closed to the measured values, except MIROC5 model.

Table 9. Average measured and projected data for the selected models with all RCPs scenarios during the period from 2006 to 2014 at Sohag Governorate.

Sohag	BCC-CSM1-1 Model	CCSM4 Model	GFDL Model	MIROC5 Model	Measured
Rad-RCP2.6	21.56	22.09	22.08	23.42	22.78
Tmax-RCP2.6	30.41	30.42	28.27	33.65	31.23
Tmin-RCP2.6	17.23	17.46	17.15	17.77	16.57
Tmean-RCP2.6	23.69	23.84	22.97	25.82	23.38
Rad-RCP4.5	21.37	22.13	22.07	23.58	22.78
Tmax-RCP4.5	30.77	30.55	28.22	33.40	31.23
Tmin-RCP4.5	17.76	17.42	17.19	17.57	16.57
Tmean-RCP4.5	24.12	23.89	22.97	25.61	23.38
Rad-RCP6.0	21.56	22.15	22.34	23.27	22.78
Tmax-RCP6.0	30.80	30.23	28.21	33.50	31.23
Tmin-RCP6.0	17.71	17.33	17.15	17.74	16.57
Tmean-RCP6.0	24.13	23.68	22.94	25.72	23.38
Rad-RCP8.5	21.52	21.97	22.32	23.45	22.78
Tmax-RCP8.5	30.76	30.38	28.22	33.46	31.23
Tmin-RCP8.5	17.43	17.54	16.93	17.66	16.57
Tmean-RCP8.5	23.96	23.87	22.84	25.68	23.38

However, RCP6.0 developed by CCSM4 model gave the highest agreement between projected and measured values for Sohag governorate (Table 10).

GLOBAL JOURNAL OF ADVANCED RESEARCH
(Scholarly Peer Review Publishing System)

Table 10. Goodness of fit parameters between measured and projected weather data by the four models at Sohag governorate

Sohag	BCC-CSM1-1 Model				CCSM4 Model			
	d	R^2	RMSE/obs	MBE/obs	d	R^2	RMSE/obs	MBE/obs
RCP2.6	0.854	0.594	0.224	-0.007	0.872	0.645	0.205	0.004
RCP4.5	0.857	0.606	0.217	0.007	0.869	0.640	0.203	0.006
RCP6.0	0.860	0.609	0.216	0.008	0.876	0.655	0.198	0.000
RCP8.5	0.860	0.610	0.219	0.002	0.874	0.654	0.200	0.004
	GFDL Model				MIROC5 Model			
	d	R^2	RMSE/obs	MBE/obs	d	R^2	RMSE/obs	MBE/obs
RCP2.6	0.852	0.597	0.220	-0.027	0.859	0.625	0.222	0.071
RCP4.5	0.855	0.610	0.216	-0.027	0.866	0.639	0.216	0.065
RCP6.0	0.857	0.613	0.221	-0.025	0.860	0.626	0.222	0.066
RCP8.5	0.863	0.633	0.211	-0.029	0.866	0.642	0.217	0.066

4. CONCLUSIONS

The Intergovernmental Panel on Climate Change Fifth Assessment Report (IPCC AR5) is a new generation of more complex models, which expected to provide more detailed and more certain projections. The improvement in these model's projections represents more processes in greater details, which implies greater confidence in their projections (Knutti and Sedlacek 2012).

Our results indicated that CCSM4 model will be suitable for the four studied governorates. This implies that the model projection of the climate of small area as one governorate was as good as projection of whole Egypt. The CCSM4 model characterized by having high resolution, i.e. 1.25º x 0.94º, compared with the other studied models. The results also indicated that MIROCS model was suitable for Kafr El-Sheik and El-Gharbia governorates, which could implies that the model can be used in successfully in the Nile Delta. The resolution of the model is 1.4º x 1.4º, which imply high level of accuracy. Furthermore, the results also indicated that BCC-CSM1-1 model was also found suitable for Kafr El-Sheik governorate, where the resolution of the model is 2.8º x 2.8º, which could implies that the model can be used in successfully in North Nile Delta.

The most suitable scenario for Kafr El-Sheik, El-Gharbia, and Sohag governorates was RCP6.0. This scenario is similar to SRES B2 climate change scenario, which is regarded as optimistic, where application of a range of technologies and strategies will result in reducing greenhouse gas emissions (Hijioka et al. 2008). Furthermore, RCP8.5 was found suitable for two governorates, i.e. Kafr El-Sheik and El-Minia. The RCP8.5 is a pessimistic scenario similar to SRES A1F1 climate change scenario, which will lead to high greenhouse gas concentration levels (Riahi et al. 2007). It is representative of the high range of non-climate policy scenarios. Most non-climate policy scenarios predict emissions of the order of 15 to 20 GtC by the end of the century (van Vuuren et al. 2011).

Our results were found in accordance with the conclusion that models have to be evaluated not only on their future projection, but also the present and past simulation (Tebaldi et al. 2007; Knutti et al., 2008; Knutti et al. 2010a; Knutti et al. 2010b). The extra model complexity in CMIP5 is likely to be an important factor to reduce uncertainty. In contrast to end users who would define model quality on the basis of prediction accuracy, climate model developers often judge their models to be better if the processes are represented in more details. Thus, the new models are likely to be better in the sense of being physically more plausible (Knutti and Sedlacek 2012). The statistical procedure used in this paper can be used by other researchers around the world, especially in developing countries to reduce uncertainty in simulation of climate change risks on agriculture and water resources.

5. REFERENCES

[1] Clarke, L. E., Edmonds, J. A., Jacoby, H. D., Pitcher, H., Reilly, J. M., and Richels, R. 2007. Sub-report 2.1a of Synthesis and Assessment Product 2.1. Climate Change Science Program and the Subcommittee on Global Change Research, Washington DC.

GLOBAL JOURNAL OF ADVANCED RESEARCH
(Scholarly Peer Review Publishing System)

[2] Cox, P., and Stephenson, D. 2007. A changing climate for prediction, Science, 317:207–208, doi: 10.1126/science.1145956.

[3] Daniel, R., Edwin, P., Michael, D., Mary, T., and Katharine, H. 2007. Climate change scenarios for the California region. Springer Science + Business Media, Climatic Change, doi: 10.1007/s10584-007-9377-6.

[4] Fujino, J., Nair, R., Kainuma, M., Masui, T., Matsuoka, Y. 2006. Multi-gas mitigation analysis on stabilization scenarios using AIM global model. Multi-gas Mitigation and Climate Policy. The Energy Journal Special, 27:343–353.

[5] Gagnon-Lebrun, F., and Agrawala, S. 2006. Progress on Adaptation to Climate Change in Developed Countries: An Analysis of Broad Trends, ENV/EPOC/GSP (2006)1/FINAL, OECD, Paris.

[6] Hijioka, Y., Matsuoka, Y., Nishimoto, H., Masui, M., and Kainuma, M. 2008. Global GHG emissions scenarios under GHG concentration stabilization targets. Journal of Global Environmental Engineering, 13:97–108.

[7] IPCC, 2007. Climate Change 2007. The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Solomon, S., D. Qin, M. Manning, et al., Eds., Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp.

[8] IPCC, 2013. Summary for Policymakers in Climate Change. The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Stocker, T. F., D. Qin, G. K. Plattner, M. Tignor, S. K.Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P. M. Midgley, Eds., Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[9] Jamieson, P. D., Porter, J. R., Goudriaan, J., Ritchie, J. T., Keulen, H., and Stol, W. 1998. A comparison of the models AFRCWHEAT2, CERES-Wheat, Sirius, SUCROS2 and SWHEAT with measurements from wheat grown under drought. Field Crops Res., 55:23–44.

[10] Joeri, R., Meinshausen, M., and Knutti, R. 2012. Global warming under old and new scenarios using IPCC climate sensitivity range estimates. Nature climate change, advance online publication, doi: 10.1038/NCLIMATE1385.

[11] Klein Tank, A. M. G., Zwiers, F. W., and Zhang, X. 2009. Guidelines on analysis of extremes in a changing climate in support of informed decisions for adaptation (WCDMP-72, WMO-TD/No.1500), 56 pp.

[12] Knutti, R. 2008. Should we believe model predictions of future climate change? Phil Philosophical Transactions of the Royal Society A, 366:4647-4664.

[13] Knutti, R., Furrer, R., Tebaldi, C., Cermak, J., and Meehl, G. A. 2010a. Challenges in combining projections from multiple climate models. Journal of Climate, 23:2739-2758.

[14] Knutti, R., Abramowitz, G., Collins, M., Eyring, V., Gleckler, P. J., Hewitson, B., and Mearns, L. 2010b. Good Practice Guidance Paper on Assessing and Combining Multi Model Climate Projections (IPCC Working Group I Technical Support Unit, University of Bern).

[15] Knutti, R. and Sedlacek, J. 2012. Robustness and uncertainties in the new CMIP5 climate model projections. Nature climate change, advance online publication, doi: 10.1038/NCLIMATE1716.

[16] Meehl, G. A., Covey, C., Delworth, T., Latif, M., McAvaney, B., Mitchell, J. F. B., Stoufffer, R. J., and Taylor, K. E. 2007. The WCRP CMIP3 multi-model dataset: A new era` in climate change research, Bulletin of the American Meteorological Society, 88:1383-1394.

[17] Moriasi, D. N., Arnold, J. G., Van Liew, M. W., Bingner, R. L., Harmel, R. D., and Veith, T. L. 2007. Model evaluation guidelines for systematic quantification of accuracy in watershed simulations. American Society of Agricultural and Biological Engineers., 50(3):885-900.

[18] Moss, R. H., Edmonds, J. A., Hibbard, K. A., Manning, M. R., Rose, S. K., van Vuuren, D. P., Carter, T. R., Emori, S., Kainuma, M., Kram, T., Meehl, G. A., Mitchell, J. F. B., Nakicenovic, N., Riahi, K., Smith, S. J., Stouffer, R. J., Thomson, A. M., Weyant, J. P., and Wilbanks, T. J. 2010. The next generation of scenarios for climate change research and assessment. Nature, 463:747-756.

[19] Riahi, K., Grübler, A., and Nakicenovic, N. 2007. Scenarios of long-term socioeconomic and environmental development under climate stabilization. Greenhouse Gases-Integrated Assessment. Special Issue of Technological Forecasting and Social Change, 74(7):887–935, doi:10.1016/j.techfore.2006.05.026.

[20] Rogelj, J., Meinshausen, M., and Knutti, R. 2012. Global warming under old and new scenarios using IPCC climate sensitivity range estimates. Nature Climate Change, 2(4):248-253, doi: 10.1038/NCLIMATE1385.

[21] Santhi, C., Arnold, J. G., Williams, J. R., Dugas, W. A., Srinivasan, R., Hauck, L. M. 2001. Validation of the SWAT model on a large river basin with point and nonpoint sources. J. American Water Resources Assoc., 37(5):1169-1188.

[22] Singh, A. K., Goyal, V., Mishra, A. K., and Parihar, S. S. 2013. Validation of CropSyst simulation model for direct seeded rice–wheat cropping system. Current science, vol.104, No. 10.

[23] Smith, S. J., and Wigley, T. M. L. 2006. Multi-gas Forcing stabilisation with the MiniCAM. The Energy Journal Special Issue, 3:373–392.

[24] Taylor, K. E., Stouffer, R. J., and Meehl, G. A. 2012.An overview of CMIP5 and the experiment design. Bulletin of the American Meteorological Society, 93:485-498.

[25] Tebaldi, C., and Knutti, R. 2007. The use of the multi-model ensemble in probabilistic climate projections. Philosophical Transactions of the Royal Society A, 365:2053-2075.

[26] Van Liew, M. W., Arnold, J. G., and Garbrecht, J. D. 2003. Hydrologic simulation on agricultural watersheds: Choosing between two models. Trans. ASAE, 46(6):1539-1551.

[27] Van Vuuren, D. P., Eickhout, B., Lucas, P. L., and den Elzen, M. G. J. 2006. Long-term multi-gas scenarios to stabilise radiative forcing - Exploring costs and benefits within an integrated assessment framework. Multi-gas Mitigation and Climate Policy. The Energy Journal Special Issue, 27:201–233.

[28] Van Vuuren, D. P., den Elzen, M. G. J., Lucas, P. L., Eickhout, B., Strengers, B. J., Van Ruijven, B., Wonink, S., and Van Houdt, R. 2007. Stabilizing greenhouse gas concentrations at low levels: an assessment of reduction strategies and costs. Climatic Change, 81:119–159.

[29] van Vuuren, D. P., Edmonds, J., Kainuma, M., Riahi, K., Thomson, A., Hibbard, K., Hurtt, G. C., Kram, T., Krey, V., Lamarque, J., Masui, T., Meinshausen, M., Nakicenovic, N., Smith, S. J., and Rose, S. K. 2011. The representative concentration pathways: an overview. Climatic Change, 109:5–31, doi: 10.1007/s10584-011-0148-z.

[30] Wayne, G. P. 2013. The Beginner's Guide to Representative Concentration Pathways. Skeptical Science, Version 1.0, http://www.skepticalscience.com/docs/RCP_Guide.pdf.

[31] Willmott, C. J. 1981. On the validation of models. Physical Geography, 2:184–194.

[32] Wise, M. A., Calvin, K. V., Thomson, A. M., Clarke, L. E., Bond-Lamberty, B., Sands, R. D., Smith, S. J., Janetos, A. C., and Edmonds, J. A. 2009. Implications of limiting CO2 concentrations for land use and energy. Science, 324:1183-1186.