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Projected Changes in Annual Temperature and Precipitation in Setif High Plains Region (North East of Algeria)

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Abstract- Known for its arid and semi-arid climate, Algeria is highly vulnerable to climate change. In this paper we present the projected temperature and precipitation changes in Setif high plains region (North East of Algeria) between three time slices: 2011- 2040 (centered on 2025), 2036-2065 (centered on 2050) and 2061-2090 (centered on 2075). MAGICC – SCENGEN5.3 (version 2) was used as a tool for downscaling the 4 chosen general circulation models (GCMs) output data. The projections are based on the SRES A2 and B2 scenarios. Under A2 scenario, The average model prediction of warming is 0.97, 1.75 and 2.88 °C across the three time slices, while the annual precipitation total is expected to reduce from -9% to -25.6%. Under B2 scenario, the four models estimate an increase in global temperature, but less than the first scenario. The average model prediction for the decrease in precipitation is -9%, -19.1% and -25.6% across the three periods.

Keywords- *Temperature, precipitation, Setif high plains, MAGICC -SCENGEN, GCMs*

I. INTRODUCTION

For many parts of the arid and semi arid regions there is an expected precipitation decrease over the next century of 20% or more. The trend of increasing annual mean temperature that has been observed for the second half of the 20th century in North Africa is likely to continue and to cause warmer and drier conditions. Temperatures are likely to rise between 2 and 3 °C while precipitation is likely to decrease between 10% and 20% until the year 2050 under SRES A1B scenario conditions [1]. Precipitation of North Africa is characterized by a wet season in winter and dry conditions in summer. The rainy season, which starts in October and lasts until April, has its maximum in the months from December to February [2]. Additionally the whole region is characterized by high inter-annual precipitation variability. Thus, long-term mean precipitation, especially in the southern region of North Africa, reflects averages over many dry years and some relatively humid years. Over the last 50 years, an increase in extreme weather events has been observed in Algeria. Experts from the 'Hydro-meteorological Institute for Training and Research' foresee a reduction in the rainy season and a rise in temperatures of around 1°C to 1.5°C by 2020, which would have fatal consequences for 30 percent of animal species. They also estimate that temperatures will rise a further 3°C by 2050 due to global warming [3].

The main objective of this study is to show the impact of global warming on annual temperature and precipitation changes during three periods of the 21st century in Setif high plains region by using four GCMs under two emission scenarios.

II. MATERIALS AND METHODS

A. Site Description

The Setif high plains region is located in the North East of Algeria. It is situated between the latitudes 35° and 36.5° N and longitudes 5° and 6° E with altitude ranging from 900m to 1300 m above sea level. Climate of this region is semi-arid, characterized by rainy cold winters and dry hot summers. The average annual rainfall is from 200 mm to 450 mm at south to north. The coldest month is January, with an average of minimum temperature of 0.4 °C. The hottest month is July, with an average of maximum temperature of 32.5 °C. In generally, the soil is calcareous earth classified as a steppic brown soil, with a pH a round 8. The dominant farming enterprise is sheep production and the purpose of the cereal cropping is to provide staple food for the farmers' family and feed for ruminants. A fallow-winter cereals rotation occupy every year more than 80 % of cultivated land.

The SCENGEN grid boxes around the Setif high plains region are 35° to 37.5° N latitude and 5° to 7.5° E longitude.

B. Model description

In order to generate climate scenario on the Setif high plains region, a relatively simple tool, namely, the MAGICC/SCENGEN 5.3 (version.2) software package was applied [4]. It is a coupled gas-cycle/climate model (MAGICC) that drives a spatial climate-change scenario generator (SCENGEN). MAGICC (Model for the Assessment of Greenhouse-gas Induced climate Change) 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 [5]. MAGICC is not a GCM, but it uses a series of reduced-form models to emulate the behavior of fully three-dimensional, dynamic GCMs. The model has been widely used by the

Intergovernmental Panel on Climate Change (IPCC) in their various assessments [6]. SCENGEN constructs a range of geographically-explicit climate change scenarios for the world by exploiting the results from MAGICC and a set of GCM experiments, and combining these with observed global and regional climate data sets. Scenarios for temperature, precipitation and cloud cover are generated with a spatial resolution of 2.5° latitude/longitude [4].

Climate within a grid box can vary substantially because of topographic relief, but SCENGEN does not capture climatic differences at this scale [4]. For impacts work, use of 9-box averages (7.5°x7.5°) produces less spatially noisy results then using single grid boxes. The values for the grid cell containing the Setif high plains are calculated as the average of the cell and the eight surrounding cells.

C. Emission scenarios selection

Future changes in GHG emissions depend on many factors, including population growth, technology, economic growth, environmental stewardship and government. The IPCC tried to capture a wide range of potential changes in GHG emissions in its Special Report on Emission Scenarios (SRES). The SRES scenarios are grouped into four scenarios families (A1, A2, B1 and B2) [7].

In this study, A2 (High) and B2 (Moderate) emission scenarios are selected, as they are found to be relevant for developing countries [8]; [9]; [10].

The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility across regions converge very slowly, which results in continuously increasing global population. Economic development is primarily regionally oriented and per capita economic growth and technological change is more fragmented and slower than in other storylines. The B2 storyline, like the A2 storyline, focuses on regional solutions to economic, social and environmental sustainability. The storyline focuses on environmental protection and social equality and is characterized by medium population and GDP growth, medium energy use, medium change in land use, medium resource availability and medium technological advancement [7].

D. Global climate Model selection

The statistics used for evaluating the performance of the 20 models to reproduce the observed climate at global scale and for the region of the Setif high plains region were: pattern correlation (r) and root mean square error (RMSE) [4]. A pattern correlation coefficient of 1.0 indicates a perfect match between the observed and simulated spatial pattern, and a root mean square error of 0.0 indicates a perfect match between the observed and simulated magnitudes [10].

As observed in table.1 and 2: ECHO-G, CCMA-31, MRI-232A and GFDLCM20 have the best performance at the global scale. However, GFDLCM21, GFDLCM20, MIROC-HI, BCCRBCM2 and MIROCMED have the best simulation at regional level. According to [4] and [11], Although its good performance at regional level, some caution should also be exercised with MIROC-HI, because this model appears to have a very high sensitivity (5.6°C), way higher than the 3° marked as best estimate in IPCC’s AR4. Based on this, the 4 GCMs used in the prediction of the future climate change of the Setif high plains region are: GFDLCM21 (USA), GFDLCM20 (USA), BCCRBCM2 (Norway) and MIROCMED (Japan).

TABLE.1: GLOBAL PERFORMANCE OF MODELS

Models	Correlation	RMSE (mm / day)
BCCRBCM2	0.793	1.311
CCCMA-31	**0.888**	0.949
CCSM--30	0.797	1.327
CNRM-CM3	0.772	1.438
CSIR0-30	0.814	1.209
ECHO---G	**0.910**	0.864
FGOALS1G	0.816	1.226
GFDLCM20	**0.868**	1.099
GFDLCM21	0.857	1.149
GISS--EH	0.733	1.512
GISS--ER	0.774	1.430
INMCM-30	0.700	1.606
IPSL_CM4	0.808	1.269
MIROC-HI	0.800	1.340
MIROCMED	0.833	1.162
MPIECH-5	0.808	1.351
MRI-232A	**0.886**	0.967
NCARPCM1	0.665	1.715
UKHADCM3	0.858	1.256
UKHADGEM	0.797	1.614

TABLE.2: REGIONAL PERFORMANCE OF MODELS

Models	Correlation	RMSE (mm /day)
BCCRBCM2	**0.831**	**0.479**
CCCMA-31	-0.903	0.358
CCSM--30	0.254	0.467
CNRM-CM3	0.556	0.108
CSIR0-30	0.533	0.339
ECHO---G	0.479	0.247
FGOALS1G	0.525	0.244
GFDLCM20	**0.988**	**0.177**
GFDLCM21	**1.000**	**0.177**
GISS--EH	-0.494	0.277
GISS--ER	-0.417	0.476
INMCM-30	0.703	0.554
IPSL_CM4	-0.825	0.633
MIROC-HI	**0.983**	0.900
MIROCMED	**0.768**	**0.044**
MPIECH-5	0.433	0.568
MRI-232A	0.759	0.398
NCARPCM1	0.657	0.351
UKHADCM3	0.711	0.286
UKHADGEM	0.411	0.164

III. RESULTS AND DISCUSSION

We examined temperature and precipitation predictions from this model using each of the four chosen GCMs independently, and used an average of output from the four GCMs to project climate change in the Setif high plains region under A2 and B2 scenario.

A. Projected annual changes in temperature

Under A2 and B2 scenario, the projected annual changes in temperature (°C) for the Setif high plains region are respectively presented in Figure.1and 2.

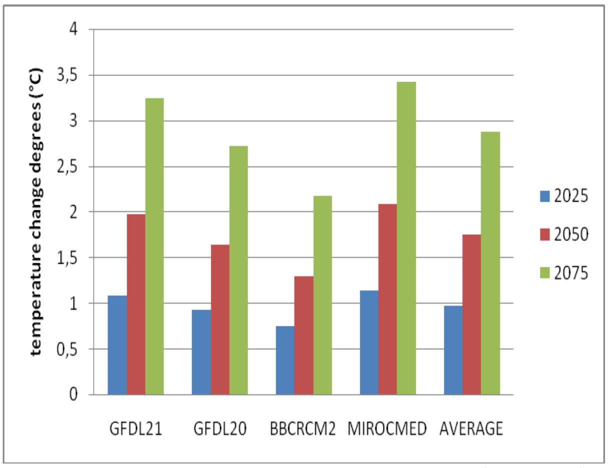

Fig.1: Estimated annual changes in temperature (°C) for the Setif high plains region in 2025, 2050 and 2075 (relative to 1990) under A2 scenario with aerosol effects.

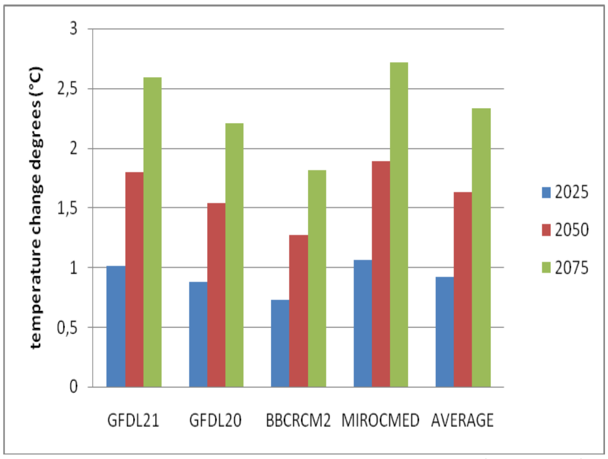

Fig.2: Estimated annual changes in temperature (°C) for the Setif high plains region in 2025, 2050 and 2075 (relative to 1990) under B2 scenario with aerosol effects.

It appears under A2 scenario, that the average model prediction for the increase in global temperature in 2025 is 0.97°C with a range of 0.92 to 1.14 °C across the four models.

By 2050, the average model prediction of warming is 1.75 °C with increase varying from 1.29 to 2.08 °C. By 2075, the four average model projections for the increase in temperature is 2.88 °C. The largest warming is projected by MIROCMED and GFDL21 with increase in temperature varying from 1.08 to 3.42°C, while the smallest warming is projected by BBCRCM2 with a range of 0.75 to 2.17 °C across the three time slices. Under B2 scenario, the four models estimate an increase in global temperature (Fig.2), but less than the A2 scenario. The average model prediction of warming in 2025, 2050 and 2075 is 0.92, 1.63 and 2.33 °C respectively. The largest warming is projected by MIROCMED and GFDL21 with warming varying from 1.01 to 2.72 °C. The smallest warming is projected by BBCRCM2 with increase varying from 0.73 to 1.81 °C.

B. Projected annual changes in precipitation

Under A2 scenario, all models predict a decrease in annual precipitation (Fig.3). The average model prediction for the decrease in precipitation is -9%, -19.1% and -25.6% in 2025, 2050 and 2075 respectively. The annual precipitation total is expected to reduce from -4% to -52.7% across the four models. The largest precipitation decreases is projected by GFDL21 with a range of -14.6% to -52.7% across the three times, while the smallest change in annual precipitation is predicted by GFDL20 with decrease varying from -4% to -9.3%.

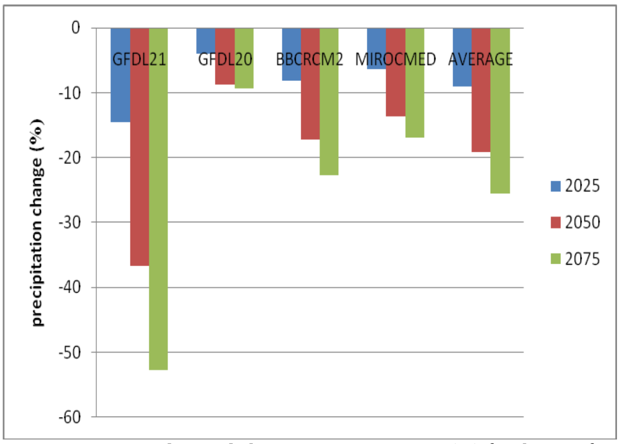

Fig.3: Estimated annual changes in precipitation (%) for the Setif high plains region in 2025, 2050 and 2075 (relative to 1990) under A2 scenario with aerosol effects.

Under B2 scenario, the four models project a decrease in annual precipitation (Fig.4), but less than the A2 scenario. The average model projection for the decrease in precipitation is -9%, -19.1% and -25.6% across the three periods. The annual precipitation is projected to decrease from -1% to -34.4% across the four models. GFDL21 project the largest decrease in annual precipitation with a values varying from -13% to -34.4%, but GFDL20 predict the smallest change with a range of -1% to -2.2%.

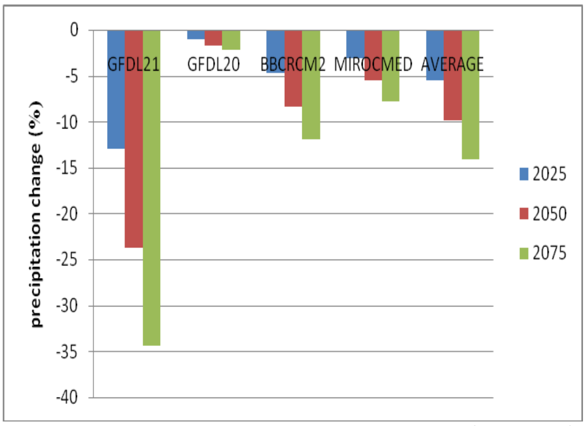

Fig.4: Estimated annual changes in precipitation (%) for the Setif high plains region in 2025, 2050 and 2075 (relative to 1990) under B2 scenario with aerosol effects.

Taking into consideration these results, in general, might be concluded that different models project different changes, but in every case the tendencies are the same, likely increase in temperature and decrease in precipitation. Predictions of the change in precipitation are more uncertain across the different models than predictions of the change in temperature. These results are in accordance with other available studies. In Iran, the HadCM2 model predicts a 2.5% decrease in precipitation until 2100 but ECHAM4 shows a 19.8% increase in this period. About temperature both, these two models predict, on the average, 3 to 3.6°C increase in temperature until decade 2100. Maximum increase in decadal temperature in ECHAM4 is about 1°C more than HadCM2 [12]. In Tunisia the change in annual rainfall is predominantly towards drying (only ECHAM4 displays wetting), although the magnitude of the drying under the A2 scenario is between 1% and 30% [13]. According to [2] projections of future climate change for Africa exhibit considerable uncertainties. A GCM average pattern might be considered to give a better presentation of regional anthropogenic climate change than the pattern derived from any single model; it will help to reduce the uncertainties in future predictions [6]. The IPCC [14] concludes that it is necessary to improve the assessments for the African regions. Dynamical and statistical downscaling assessments also need major improvements for the African domain. For instance it is necessary to gain a better understanding of climate variability in this region, which involves the inclusion of specific feedback mechanisms e.g. of the oceans and of land use change.

IV. CONCLUSION

This work was designed to present a clearer understanding of what type of climate that Setif high plains region are to experience during three times of the 21st century. The results indicate that under A2 scenario, the average model prediction of warming is 0.97, 1.75 and 2.88 °C across the three periods, while the annual precipitation total is expected to reduce from -4% to -52.7% across the four models and the three times. Under B2 scenario, all models predict an increase in temperature, but less than the A2 scenario. The four models project a decrease in annual precipitation with a range of -1% to -34.4% across the four models and the three times. The largest and the smallest warming is projected by MIROCMED and BBCRCM2 respectively, while the largest and the smallest decreasing in annual precipitation is projected by GFDL21 and GFDL20 respectively. These results show that climate changes will have a dramatic effect on the water resources and consequently cause a decrease in agriculture productivity of this region which depends almost entirely on precipitation as the main source of water. Knowledge of the possible behavior of the climate in the region, in the event of climatic changes- the basis for any assessment of the vulnerability of the region- requires that the region possess a general circulation model, with a mesh model focusing on North Africa. This is a basic tool that would seem essential in order to help the countries in the region to achieve, develop, and adapt to the local climatic context.

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