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An Assessment of Temperature and Precipitation Change Projections in Muscat, Oman from Recent Global Climate Model Simulations

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***Abstract*— Oman is vulnerable to the impacts of climate change, the most significant of which are increased temperature, less and more erratic precipitation, see level rise (SLR) and desertification. The objective of this research is to investigate the potential variation of precipitation and temperature in Muscat, the capital city of Sultanate of Oman in future. We used the MIROC general circulation model (GCM) output (maximum and minimum temperatures and precipitation) from the Representative Concentration Pathways (RCPs) 2.6, 4.5, 6.0 and 8.5 scenarios of the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) for assessing changes in climate in the period of 2080-2099 compared to the baseline period of 1986-2005. The spatial mismatch between GCM grid scale and local scale was resolved by applying the LARS stochastic Weather Generator (WG) model. The results obtained for 4 scenarios indicate a significant warming in future, which ranges from 0.93°C (minimum temperature by 1.1°C and maximum temperature by 0.86°C) for the lowest scenario, RCP 2.6, to 3.1°C (minimum temperature by 3.2°C and maximum temperature by 3.0°C) for the highest one, RCP 8.5, relative to baseline level. The differences in the precipitation projections between the scenarios are much greater compared to consistent warming depicted in temperatures. The results reveal -36.4% and -36.0% decreases in precipitation for the RCP 2.6 and RCP 4.5 scenarios, respectively, while, RCP 6.0 and RCP 8.5 scenarios predict increase in precipitation in a range from 9.6% to 12.5%, respectively during 2080-2099 compared to 1986-2005 period. These results need to be further improved by adopting more GCMs, which will provide potential changes in a consistent range.**

I. INTRODUCTION

Observed and projected increases in temperature and precipitation variability are perhaps the most influential climate driven changes to impact water systems (Parry et al., 2007). Located in an arid region, the climate of Oman is vulnerable to the potential impacts of climate change, the most significant of which are increased average temperatures, less and more erratic precipitation, sea level rise (SLR) and desertification. Oman is primarily concerned due to its chronic water stress and lack of resilience (institutional, infrastructure and social) against climate change.

Groundwater represents about 78% of the water supply in Oman. Owing to a lack of data and the very slow reaction of groundwater systems to changing recharge conditions, impacts of climate change on groundwater are poorly understood. Groundwater resources are related to climate change through hydrologic processes, such as precipitation and evapotranspiration, and through interaction with surface water. With increased evapotranspiration as a result of higher air temperature and decreased precipitation, the impact of climate change will result in declining groundwater recharge (Eckhardt and Ulbrich, 2003; Brouyere et al., 2004) and alter the associate temperature distribution in the subsurface. For example, in the Ogallala Aquifer region, projected natural groundwater recharge decreases more than 20% in all simulations with warming of 2.5°C or greater (Rosenberg et al., 1999).

Integrating climate change mitigation and adaptation in development strategies and policies is a must for Oman which is at the early stage of economic and industrial development. Thus far in Oman, the scientific knowledge about the climate change and its impacts on the hydro-meteorological extremes has not been fully studied thereby making it difficult to assess future risks. Therefore, the main objective of this research is to investigate the potential variation of precipitation and temperature in Muscat, the capital city of Sultanate of Oman in future.

II. STUDY AREA

Oman located in south-Eastern corner of the Arabian Peninsula, encompasses a diverse range of topography, including mountain ranges, low land, coastal areas and arid deserts. The coastal line of Oman extends over 3165 km and experiences very severe tropical cyclones. The supper cyclonic storm, hurricane Gonu in 2007 led to the worst natural disaster on record in Oman, with total rainfall reached 610 mm near the cost. The cyclone and flash flood caused about $4 billion in damage (2007 USD) and 49 deaths (Rafy and Hafez, 2008). The climate of the country is mainly arid or semiarid, which receives less than 100 mm in annual rainfall on average compared to annual global average of 1123 mm.

Muscat, the capital city of Oman is a coastal city (Fig.1), which accommodates 29.5% of the total population in Oman in 2010. The average precipitation of Muscat is 81 mm over the period 1977-2011 and it shows statistically weak increasing trend at an average rate of 6 mm/10 yr. The rainfall pattern proved to be irregular, averaging rain on only around 7 days per year. Consequently, number of consecutive days of no rainfall is relatively high, which was estimated to be about 225 days per year over the period 1977-2011. The daily maximum temperature in Muscat fluctuates between 17 and 49°C, and the daily minimum temperature is between 10 and 40°C over the period 1986-2011.

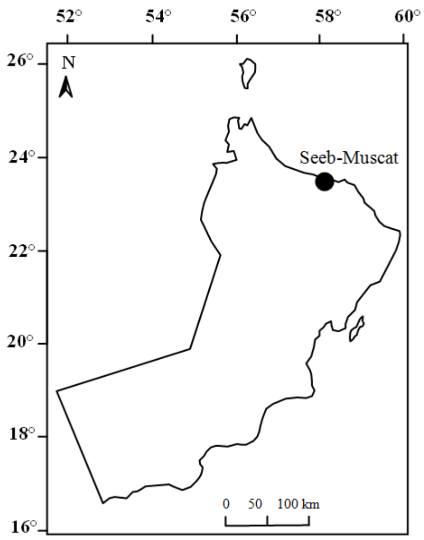

Fig. 1. Study area in Oman

III. METHODOLOGY

Observed precipitation and temperature data in the Muscat airport meteorological station for the period of 1986-2005 were obtained. For the future climates, we used the MIROC general circulation model (GCM) output (maximum and minimum temperatures and precipitation) from the Representative Concentration Pathways (RCPs) 2.6, 4.5, 6.0 and 8.5 scenarios in the periods of 1986-2005 and 2080-2099. The four RCPs are based on multi-gas emission scenarios. They are being used to drive climate model simulations planned as part of the World Climate Research Programme's Fifth Coupled Model Intercomparison Project (CMIP5) (Taylor et al. 2009).

The spatial mismatch between GCM grid scale and local scale was resolved by applying statistical downscaling method. A stochastic weather generator (LARS-WG) used in this study serve as a computationally inexpensive tool to produce multiple-year climate change scenarios at the daily time scale which incorporate changes in both mean climate and in climate variability (Semenov & Barrow, 1997). LARS-WG can be used for the simulation of weather data at a single site under both current and future climate conditions. These data are in the form of daily time-series for a suite of climate variables, namely, precipitation (mm), maximum and minimum temperature (°C) and solar radiation ($MJm^{-2}day^{-1}$). The simulation of precipitation occurrence is based on distributions of the length of continuous sequences, or series, of wet and dry days. To developed future scenarios, the mean of the empirical distributions for wet and dry spell length from the baseline (1986-2005) and future time period (2080-2099) were calculated for each month. The relative change in length of wet (or dry) series was calculated as follows.

Relative change in length = length2080-2099 / length1986-2005 (1)

Similarly, the relative change in standard deviation (St.dev.) of minimum and maximum temperatures and the mean change in precipitation amount were calculated as follows.

Relative change in St.dev = St.dev.2080-2099 / St.dev.1986-2005 (2)

Relative change in Precipitation = pre.2080-2099 /pre.1986-2005 (3)

For monthly mean changes in maximum and minimum temperatures, the monthly mean changes in these values between the future and baseline periods were considered.

IV. RESULTS AND DISCUSSIONS

We used the MIROC model output of maximum and minimum temperatures and precipitation from the RCPs 2.6, 4.5, 6.0 and 8.5 scenarios for assessing changes in climate in the period of 2080-2099 compared to the baseline period of 1986-2005. An example of the scenario file developed for the RCP4.6 is shown in Fig. 2.

The scenario files developed for each scenario were used with the observations during 1986-2005 to produce time series of weather variable for the period of 2080-2099. Table 1 shows a summary of weather variables and their relative change in future compared to baseline time period. Figure 3 depicts accumulative probability distributions of three variables in baseline period and four scenarios in the future. According to figures 3 a) and b), there is a consistent warming in both minimum and maximum temperatures with different magnitudes for all scenarios during 2080-2099 compared to observations in 1986-2005 period. RCP8.5, which is representative of the high range of non-climate policy scenarios (subsequent radiative forcing of $8.5Wm^{-2}$ in 2100), predicts the highest warming of 3.2 and 3.05°C for minimum and maximum temperatures, respectively. Similarly, RCP2.6, which assumes drastic policy interventions to reduce greenhouse gas emissions (subsequent radiative forcing of 2.6 Wm^{-2} by 2100), predicts the lowest warming of 1.01 and 0.86°C for minimum and maximum temperatures, respectively. Warming predicts by two other scenarios varies between RCP8.5 and RCP2.6 in similar magnitudes.

```
//  Columns are:
//  [1]     month
//  [2]     relative change in monthly mean rainfall
//  [3]     relative change in duration of wet spell
//  [4]     relative change in duration of dry spell
//  [5]     absolute changes in monthly mean min temperature
//  [6]     absolute changes in monthly mean max temperature
//  [7]     relative changes in daily temperature variability
//  [8]     relative changes in mean monthly radiation
[VERSION]
LARS-WG5.5
[NAME]
Muscat_RCP46
[BASELINE]
1986
[FUTURE]
2080
[GCM PREDICTIONS]
Jan     0.68  0.94  1.06  1.09  1.09  0.86  1
Feb     1.40  0.80  0.66  1.09  1.09  0.71  1
Mar     0.34  0.86  3.99  1.09  1.09  1.04  1
Apr     1.62  0.84  1.51  1.09  1.10  0.94  1
May     0.41  1.11  1.39  1.09  1.08  0.86  1
Jun     0.58  0.74  0.84  1.06  1.05  0.78  1
Jul     3.69  0.81  1.28  1.04  1.02  0.97  1
Aug     4.47  1.70  0.52  1.03  1.02  0.77  1
Sep     1.34  0.76  1.17  1.03  1.02  0.93  1
Oct     9.27  1.54  1.12  1.05  1.05  1.00  1
Nov     0.08  0.68  2.06  1.06  1.06  0.80  1
Dec     0.50  0.78  1.55  1.09  1.09  0.70  1
[END]
```

Fig. 2. A scenario file developed to use in the LARS-WG for the MIROC global climate model for the RCP4.6 scenario for the time period 2080–2099 at Muscat.

The differences in the precipitation projections between the scenarios are much greater compared to consistent warming depicted in temperatures. The results reveal -36.4% and -36.0% decreases in precipitation for the RCP 2.6 and RCP 4.5 scenarios, respectively, while, RCP 6.0 and RCP 8.5 scenarios predict increase in precipitation in a range from 9.6% to 12.5%, respectively during 2080-2099 compared to 1986-2005 period. Figure 3 c) depicts that the RCP8.5 scenario predicts the potential of very extreme precipitation events in future, which may increase the risk of floods in our study area.

V. Conclusions and Recommendations

This study was conducted to investigate the potential variation of precipitation and temperature in Muscat, the capital city of Sultanate of Oman in future. We used the MIROC general circulation model output (maximum and minimum temperatures and precipitation) from the RCPs 2.6, 4.5, 6.0 and 8.5 scenarios of the IPCC Fifth Assessment Report for assessing changes in climate in the period of 2080-2099 compared to the baseline period of 1986-2005. LARS-WG was used for the simulation of weather data under both current and future climate conditions.

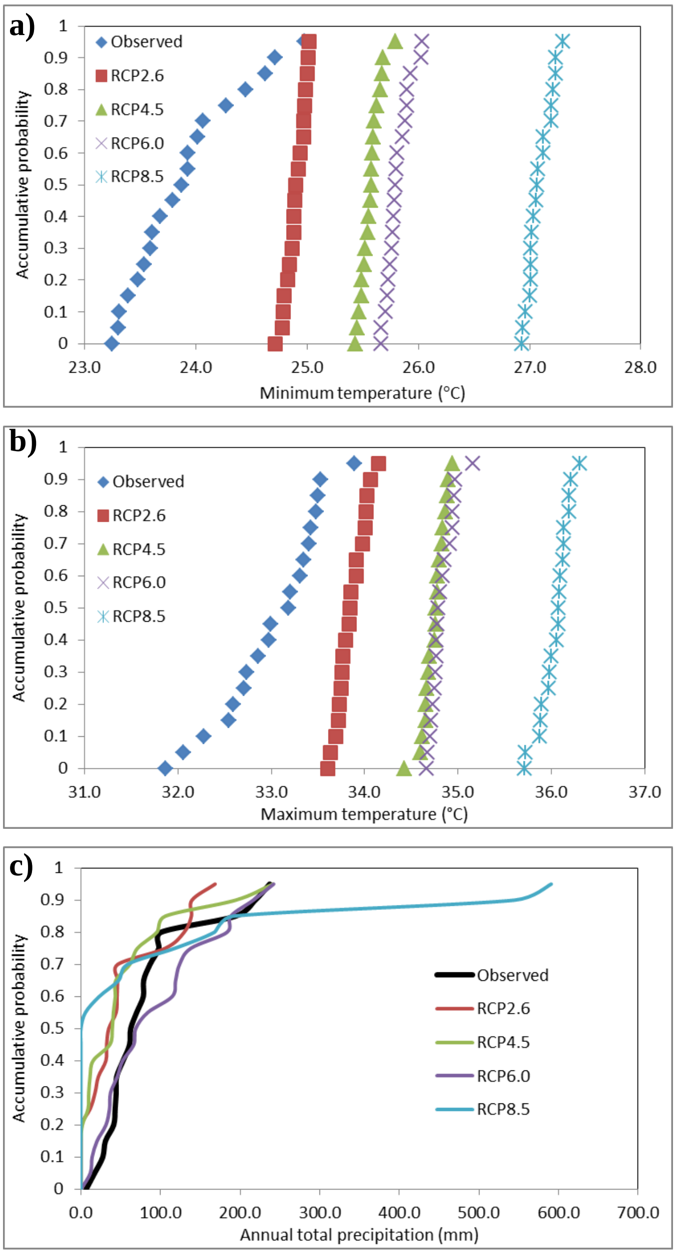

Fig.3 Probability distributions of weather variables in the baseline and future time periods

The results obtained for 4 scenarios indicate a significant warming in future, which ranges from 0.93°C (minimum temperature by 1.1°C and maximum temperature by 0.86°C) for the lowest scenario, RCP 2.6, to 3.1°C (minimum temperature by 3.2°C and maximum temperature by 3.0°C) for the highest one, RCP 8.5, relative to baseline level.

TABLE I
A SUMMARY OF WEATHER VARIABLES CHANGE DURING 2080-2099 COMPARED TO 1986-2005 PERIOD

Data	**Minimum Temperature**		**Maximum Temperature**		**Rainfall**	
	Annual average value (°C)	**Relative change (°C)**	**Annual average value (°C)**	**Relative change (°C)**	**Annual total (mm)**	**Relative change (%)**
Observations	23.89		32.99		79.79	
RCP 2.6	24.9	1.01	33.85	0.86	50.75	-36.40
RCP 4.5	25.57	1.68	34.74	1.75	51.09	-35.97
RCP 6.0	25.81	1.92	34.83	1.84	89.76	12.50
RCP 8.5	27.09	3.2	36.04	3.05	87.41	9.55

The results reveal -36.4% and -36.0% decreases in precipitation for the RCP 2.6 and RCP 4.5 scenarios, respectively, while, RCP 6.0 and RCP 8.5 scenarios predict increase in precipitation in a range from 9.6% to 12.5%, respectively during 2080-2099 compared to 1986-2005 period. RCP8.5 scenario alone predicts the probability of very extreme precipitation events in future which may have implications for planning and decision making for flood mitigation infrastructures, land-use regulations and building codes. The differences in the precipitation projections between the scenarios are much greater compared to consistent warming depicted in temperatures. These results need to be further improved by adopting more GCMs, which will provide potential changes in a consistent range. The results of this study can be integrated with hydrological and flood models so that risk scenarios can be constructed for future time periods.

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REFERENCES

[1] M. Parry, O. Canziani, J. Palutikof, P. V. Linden and C. Hanson, "Climate change 2007: Impacts, Adaptation and Vulnerability. Summary for policymakers", Cambridge University Press, New York, 2007.

[2] K. Eckhardt and U. Ulbrich, "Potential impacts of climate change on groundwater recharge and streamflow in a central European low mountain range," *Journal of Hydrology*, vol. 284, pp. 244-252, 2003.

[3] S. Brouyere, G. Carabin and A. Dassargues, "Climate change impacts on groundwater resources: modelled deficits in a chalky aquifer, Geer basin, Belgium," *Hydrogeology Journal*, vol. 12, pp.123-134, 2004.

[4] N. J. Rosenberg, D. J. Epstein, D. Wang, L. Vail, R. Srinivasan and J. G. Arnold, "Possible impacts of global warming on the hydrology of the Ogallala Aquifer region," *Climatic Change*, vol. 42, pp. 677–692, 1999.

[5] M. E. Rafy, and Y. Hafez, "Anomalies in meteorological fields over northern Asia and its impact on Hurricane Gonu," *28th Conference on Hurricanes and Tropical Meteorology*, pp. 1–12, 2008.

[6] K. Taylor, R. J. Stouffer and G. A. Meehl, "A summary of the CMIP5 Experiment Design" [Online]. Available: http://cmip-pcmdi.llnl.gov/cmip5/docs/Taylor_CMIP5_design.pdf

[7] M. A. Semenov and E. M. Barrow, "Use of a stochastic weather generator in the development of climate change scenarios," *Climatic Change*, vol. 35, pp.397-414, 1997.