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Forecasting of Climate Changes of Ayeyarwady Delta in Myanmar during 21st Century by MRI-AGCM3.2S Dataset

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ABSTRACT

Climate change is associated with both gradual changes in the long-term temperature and precipitation patterns in an area. In this study, MRI-AGCM3.2S was used to simulate the current climate (1981-2005) and the forecasted climate for the near future (2020-2044) and far future (2075-2099). MRI-AGCM3.2S is developed by the Meteorological Research Institute (MRI) and Japan Meteorological Agency (JMA). Linear scaling and lumped quantile mapping methods are used in bias-correction for MRI-AGCM3.2S under the Special Report on Emission Scenarios (SRES) of A1B. Bias correction is capable of improving the General Circulation Model (GCM) simulated outputs to a certain degree. In this study, the coefficient of determination (R2) and root mean square error (RMSE) are quantified before and after bias correction. Based on the performances, the lumped quantile mapping technique was identified as a suitable method for correcting the bias. Changes in temperature and precipitation are projected to vary by region and month. The key findings on future climates in each of the regions are presented in terms of temperature increase and precipitation change.

Key Words: *Ayeyarwady delta, MRI-AGCM3.2s, SRES-A1B, Bias Correction, 21st Century.*

1. INTRODUCTION

Climate change could have an effect both on the long-term water availability and short-term variability of water resources in many regions of the world [1]. Almost all parts of the world are now facing the negative impacts of climate change. However, the intensity and characteristics of the impact vary significantly from region to region. It is of utmost importance to assess the impact of climate change on hydrology at regional scale to better understand the potential change in water resources. Some forms of climate change experienced by mankind in recent years include more frequent floods, stronger hurricanes, typhoons and other storms, as well as extended droughts and heat waves [2].

Myanmar ranks one of the top countries vulnerable to the effect of climate change. The country is experiencing an increase in temperature and a change in precipitation patterns over the past decade [3]. Myanmar experiences a tropical-monsoon climate with three dominant seasons: the January-to-May pre monsoon, the June-to-September monsoon and the October-to-December post monsoon. Climate change impact on different regions of Myanmar have been recorded based on some observed trends such as an increase in mean temperature, an increase in overall rainfall in most areas with a declining trend in some areas, late onset and early termination of the south-west monsoon over the last six decades according to the record by Department of Meteorology and Hydrology of Myanmar [4].

In Myanmar, the Ayeyarwady has been identified as a vulnerable areas to climate change because it receives very high rainfall. Currently, general circulation models (GCMs) are the most effective tools for simulating present climate and projecting future climate. The outputs of GCMs with various spatial resolutions can be used as inputs to hydrological model simulations to assess the impact of climate change on hydrology and water resources [5].

This research intends to project the selected sixteen stations of temperature and precipitation in Ayeyarwady Delta derived from 20km mesh MRI-AGCM was calibrated with baseline to the observed data for the period of 1981-2005. Projections for temperature and precipitation are made for near future (2020-2044) and far future (2075-2099). MRI-AGCM3.2S, Atmosphere-

Ocean General Circulation Model (AOGCM) used in this study is a global hydrostatic fully coupled AOGCM developed by the Meteorological Research Institute (MRI) and Japan Meteorological Agency (JMA), with a horizontal grid size of about 20km.

2. STUDY AREA

Ayeyarwady Delta is covering the large parts of Ayeyarwady, Bago and Yangon regions. Monsoonal climate for the delta leads to average annual precipitation of about 1500-2000 mm in the north, 2500 mm in the southeast and 3500 mm in the southwest. The maximum and minimum temperatures are about 37°C and 22°C. In Ayeyarwady Delta, sixteen stations are selected and the projection of climate change was done. These stations are Henzada, Maubin, MyaungMya, Pathein, Zalun (in Ayeyarwady region), Bago, Gyobingauk, Phyu, Pyay, Shwegyin, TaungOo, Tharrawady, ZaungTu (in Bago region), Hmawbi, Kabaaye, and Mingaladone (in Yangon region). The locations of the study area in Ayeyarwady are shown in Figure-1.

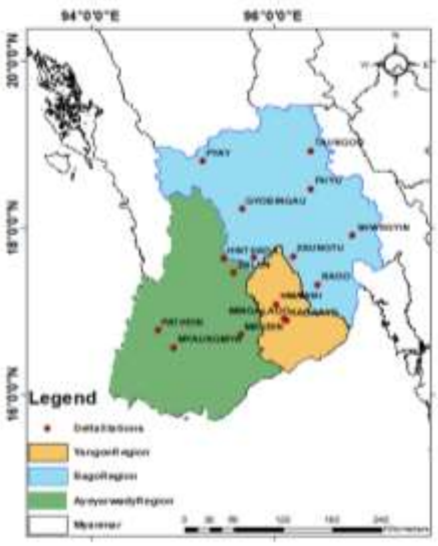

Figure 1: Location Map of the Study Area in Ayeyarwady Delta.

3. METHODOLOGY

Observation data from Department of Meteorology and Hydrology (DMH), Myanmar were utilized for validation of MRI-AGCM3.2S generated temperature and precipitation. The MRI-AGCM3.2S (the 20-km model) is the latest atmospheric GCMs based on a model jointly developed by the Japan Meteorological Agency (JMA) and the Meteorological Research Institute (MRI) is used to project for three 25-year periods: 1981-2005 (present climate), 2020-2044 (near future climate), and 2075-2099 (future climate). Many parameterization schemes for various physical processes are newly developed and introduced into the model by both JMA and MRI. The schemes are implemented to be switched easily from the conventional schemes. The models with 20-km resolution are referred to as MRI-AGCM3.2S (where 'S' refers to super-high resolution).

The SRES scenarios define only the changes in anthropogenic emissions and not the concurrent changes in natural emissions due either to direct human activities such as land-use change or to the indirect impacts of climate change. The set of scenarios consists of six groups drawn the four families: one group each in A2, B1, B2, and three groups within the A1 family, characterizing alternatives for energy technologies. A1F1 (fossil fuel intensive), A1B (balanced) and A1T (predominantly non-fossil fuel). From the SRES family of emission scenarios, only three were used in the CMIP3 climate change simulation runs for the IPCC Fourth Assessment Report: SRES-B1, SRES-A1B and SRES-A2. In this study, the data used for future projection were based on SRES-A1B scenario. The SRES-A1B scenario are more or less equivalent in term of CO_2 concentration. Figure-2 shows time slice future projection and cumulus scheme of MRI-AGCM.

The GCMs model performance can be determined by checking statistical parameters such as Coefficient of Determination (R^2), and Root Mean Square Error (RMSE). R^2 bigger than 0.5 can be considered reasonable value for hydrological purposes and RMSE value closer to zero indicates better the performance of the model. These data were bias-corrected using not only linear scaling method but also lumped quantile mapping method. Firstly temporal correction with fixed ratio was done using linear scaling method. Then adjustment of correction factor for each class was done based on frequency distribution. Procedure of bias correction are as follows:

- Creation of region mask/river basin mask and administration mask
- Finding corresponding grid for each observation station
- Re-ordering model output

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- Detection of model mean bias, calculating frequency distribution
- Bias correction considering frequency distribution

In this study bias correction was done using developed by Kenji Tanaka, Disaster Prevention Research Institute (DPRI), Kyoto University.

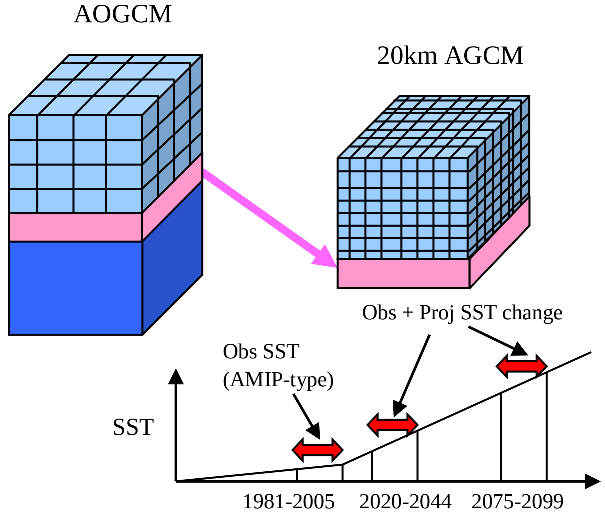

Figure 2: Time Slice Future Projection

Source: [6]

4. RESULTS

4.1 Bias Correction for Temperature

Table-1 shows statistics of temperature reproduced by the downscaling model with MRI-AGCM3.2S outputs, before bias correction and after bias correction for each month. It is found that R^2 value increased up to 0.99 and RMSE value nearly 0.1 in 90th percentile after doing bias correction. It was seen that bias-correction techniques were capable in correcting the temperature with MRI-AGCM3.2S outputs adequately, in all seasons.

Table-1: Statistics of Temperature Correction

Month	Statistics	Before Bias Correction	After Bias Correction	
		MRI-AGCM3.2S	Linear Scaling	Lumped Quantile Mapping
Jan	R^2	0.85	0.95	0.97
	RMSE	1.44	0.27	0.18
Feb	R^2	0.83	0.97	0.94
	RMSE	2.38	0.16	0.49
March	R^2	0.93	0.87	0.99
	RMSE	2.51	0.32	0.28
April	R^2	0.98	0.85	0.98
	RMSE	1.29	0.36	0.10
May	R^2	0.46	0.84	0.99
	RMSE	0.47	1.09	0.20
June	R^2	0.58	0.76	0.88
	RMSE	1.89	1.06	0.71
July	R^2	0.77	0.86	0.90
	RMSE	1.92	0.94	0.68
August	R^2	0.46	0.92	0.99
	RMSE	1.59	0.84	0.25
September	R^2	0.86	0.97	0.91
	RMSE	1.41	0.72	0.32
October	R^2	0.98	0.92	0.99
	RMSE	1.39	0.57	0.36
November	R^2	0.84	0.99	0.98
	RMSE	0.32	0.22	0.23
December	R^2	0.77	0.96	0.94
	RMSE	0.64	0.29	0.48

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The mean bias, defined as the difference between GCM temperature and observed temperature, was calculated for regions. The bias value ranged from -4 to 4. It was found that mean bias was between -2 and 2 in most months. Figure-3 shows the temperature mean bias proportion of grid cells for each region over each month.

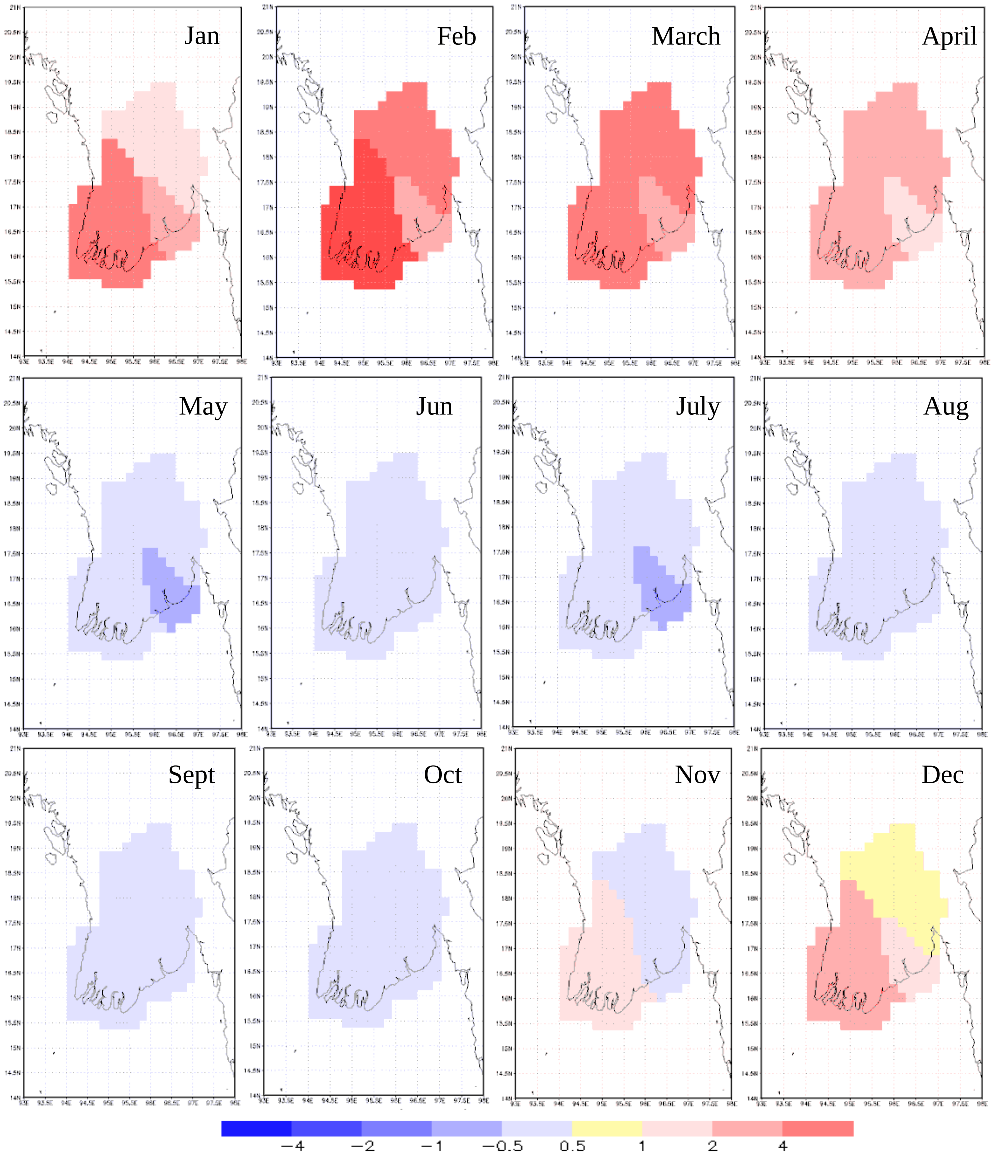

Figure 3: Spatial Distribution of Temperature Mean Bias.

4.2 Bias Correction for Temperature

Lumped quantile mapping bias correction method is capable of improving the GCM-simulated rainfall to a certain degree. It is found that R^2 value increased up to 0.99 in 90th percentile after bias correction by lumped quantile mapping method for monthly precipitation shows in Table-2.

Table-2: Statistics of Precipitation Correction

Month	Statistics	Before Bias Correction	After Bias Correction	
		MRI-AGCM3.2S	Linear Scaling	Lumped Quantile Mapping
Jan	R^2	0.78	0.99	0.98
	RMSE	15.02	22.99	20.72
Feb	R^2	-0.94	0.99	0.99
	RMSE	28.87	31.04	17.39
March	R^2	0.89	0.50	0.93
	RMSE	15.60	23.78	8.84
April	R^2	-0.74	0.54	0.62
	RMSE	30.62	34.13	30.10

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May	R^2	-0.91	0.84	0.75
	RMSE	28.8	30.86	11.82
June	R^2	0.99	0.44	0.99
	RMSE	27.43	19.10	12.06
July	R^2	-0.41	-0.88	0.38
	RMSE	31.08	20.88	6.59
August	R^2	-0.74	-0.93	0.99
	RMSE	35.99	20.68	12.78
September	R^2	0.98	0.74	0.90
	RMSE	31.50	24.79	9.17
October	R^2	-0.99	-0.01	0.58
	RMSE	24.77	21.72	11.15
November	R^2	0.79	0.31	0.63
	RMSE	34.84	26.84	9.17
December	R^2	-0.63	-0.95	0.93
	RMSE	7.09	16.99	2.20

Figure-4 shows the precipitation mean bias proportion of grid cells for each region over each month. The bias value ranged from 0.2 to 5.0. It was found that mean bias was between 0.5 and 2.0 in most months. Because only few stations are located within some regions, these data sets do not capture the realistic distribution of precipitation in this large area (over 20,000 km^2).

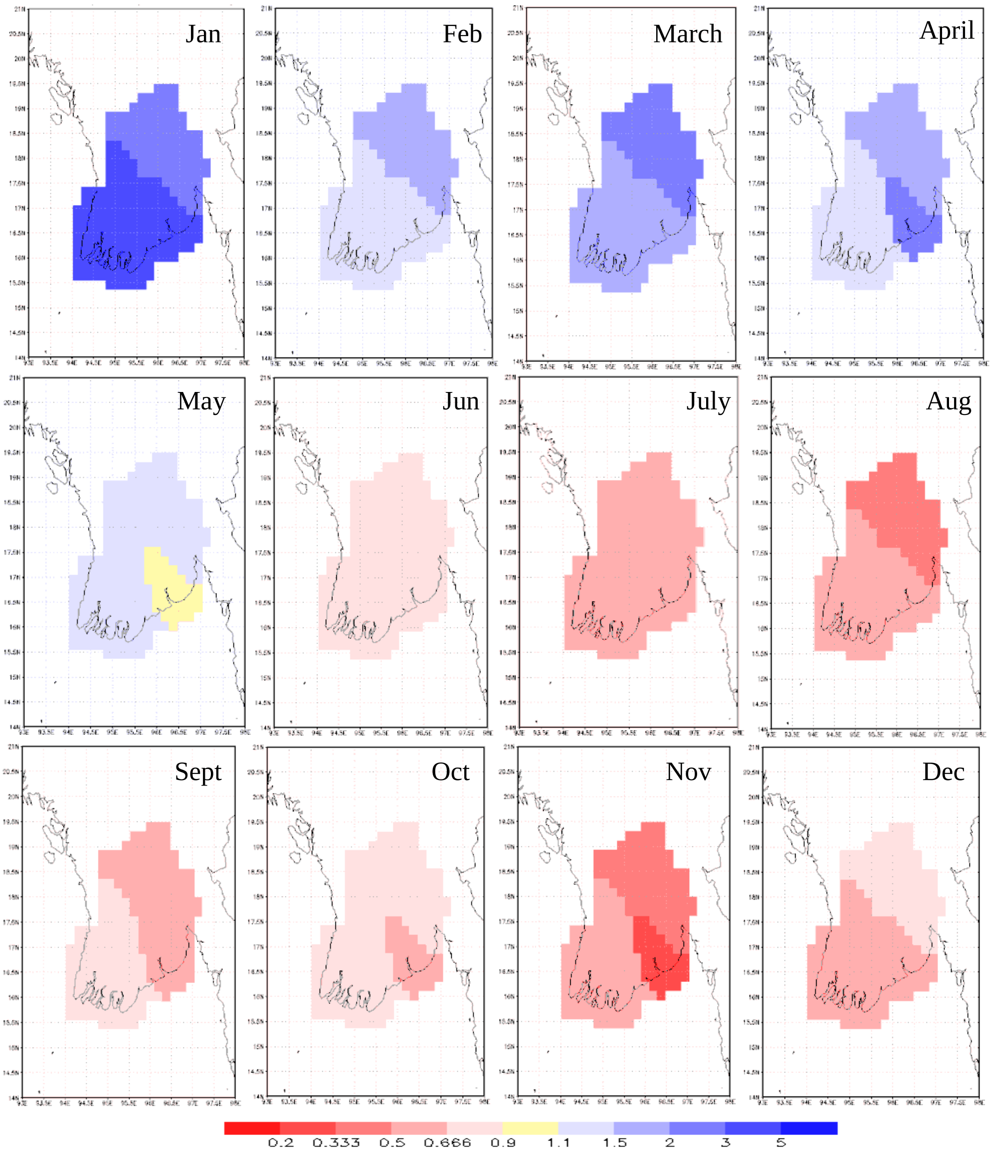

Figure 4: Spatial Distribution of Precipitation Mean Bias.

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4.3 Temperature Projection

Figure-5 and Figure-6 show the average monthly temperature of (2020-2044) and (2075-2099) periods under SRES-A1B scenario with the baseline data (1981-2005) for Ayeyarwady, Bago and Yangon regions which are predicted using MRI-AGCM3.2S. It is projected that the highest average temperature about 31.5°C (Ayeyarwady), 31.6°C (Bago) and 32.4°C (Yangon) in the month of May during the 21st century.

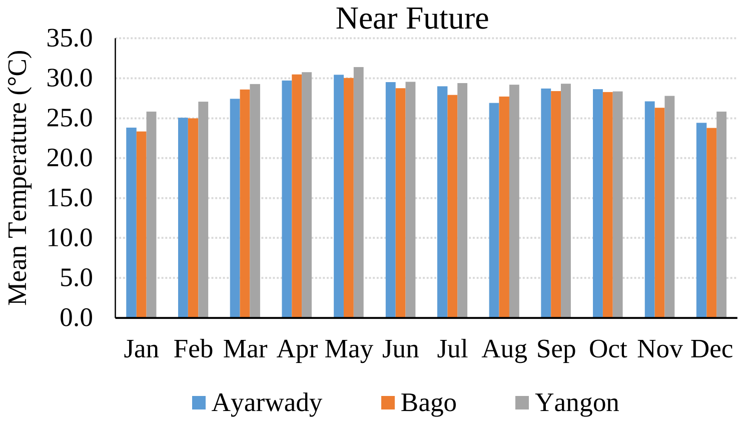

Figure 5: Average Monthly Temperature in Near Future

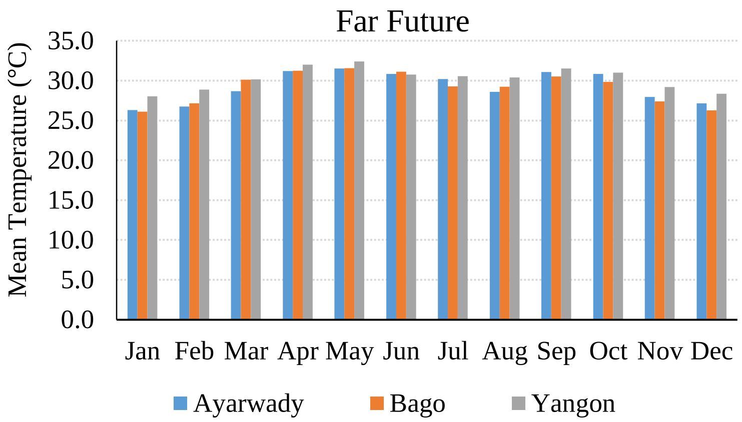

Figure 6: Average Monthly Temperature in Far Future

The box and whisker plots of each time period indicate that the highest values of average annual temperature are expected to increase in the future, but the projected changes of 75th percentiles, medians, 25th percentiles and lowest values are not unidirectional and vary depending on scenarios and time periods. The box represents the middle 50% range, while the bar represents the median value. The whiskers at the two ends represent extreme projections. The highest average annual projection changes in near future and far future for Ayeyarwady Delta are projected by MRI-AGCM3.2S under A1B scenarios relative to the baseline (1981-2005) are shown in Figure-7 and Figure-8. In these figures, the first quarter (Q_1) value mean that value with the cumulative probability is 25% and third quarter (Q_3) is the value with cumulative probability is 75%. Future changes of average annual temperature are projected about 0.1°C-1.8°C (2020-2044), 0.8°C-3.6°C (2075-2099).

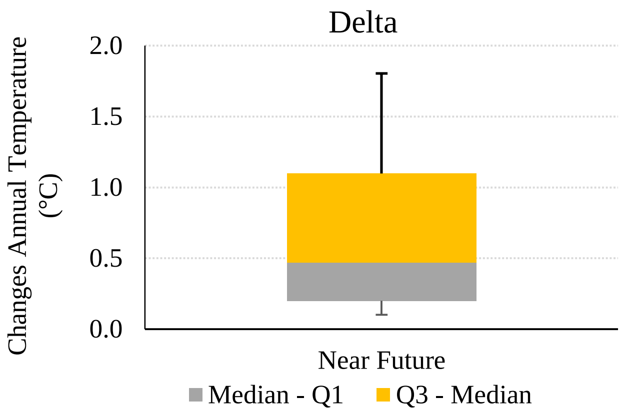

Figure 7: Changes in Average Annual Temperature for Near Future Periods in Ayeyarwady Delta Zone

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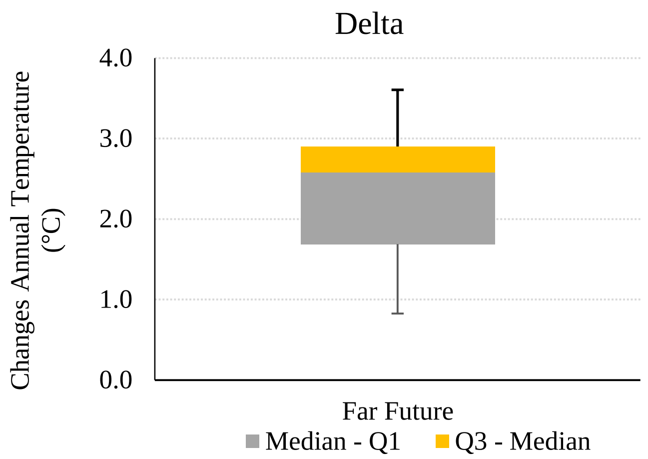

Figure 8: Changes in Average Annual Temperature for Far Future Periods in Ayeyarwady Delta Zone

4.3 Precipitation Projection

From this study, it is found that the average monthly precipitation changes are fluctuated for the three regions of Ayayarwady, Bago and Yangon with respect to the baseline period (1981-2005) using MRI-AGCM3.2S under A1B scenario and are shown in Figure-9 for near future, Figure-10 for far future. The highest changes value are occurred in the month of June for all regions during the end of 21st century.

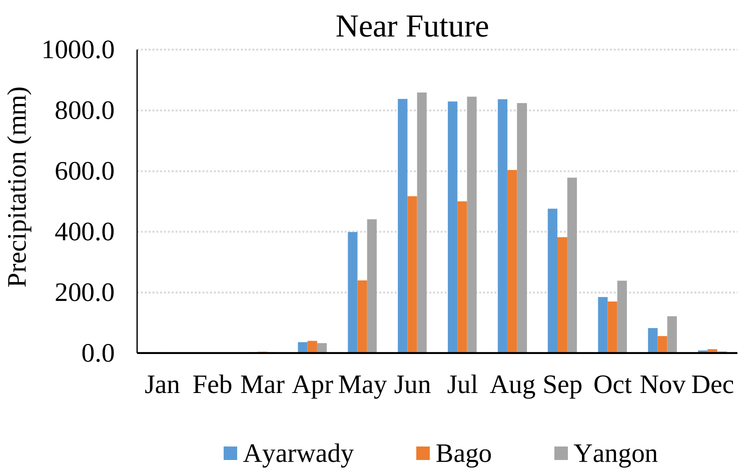

Figure 9: Changes in Average Monthly Precipitation for Three Regions in Near Future Periods

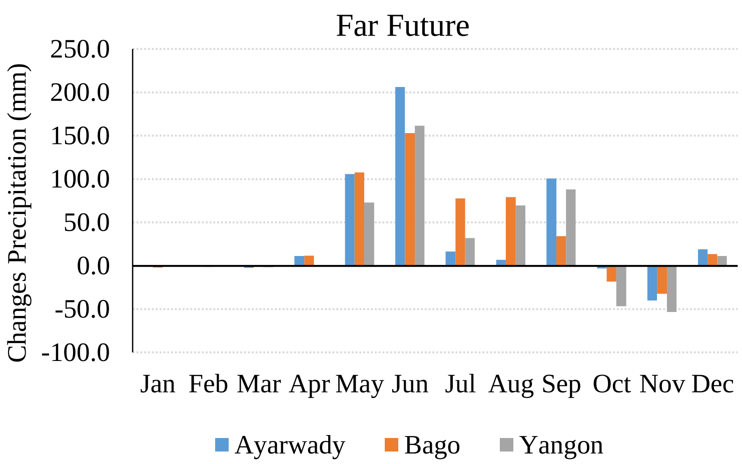

Figure 10: Changes in Average Monthly Precipitation for Three Regions in Far Future Periods

The summarized result of changes (%) under SRES-A1B scenario show in Table-3, and it is predicted that the pre-monsoon and monsoon rainfall will increase and post-monsoon rainfall will decrease by significant amount in both future periods. This result implies that the average annual Delta precipitation increases in the future periods with the baseline period (1981-2005).

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Table 3: Changes in Average Precipitation (%) Compared to (1981-2018) in Ayeyarwady Delta

Difference (%)	SRES-A1B Scenario	
	(2020-2044)	(2075-2099)
Pre Monsoon	27.4	31.5
Monsoon	11.9	14.2
Post Monsoon	-7.3	-15.8
Annual	11.5	12.9

5. SUMMARY

In this research, climate simulation for the near future (2020-2044) and the far future (2075-2099) of the 21st century under IPCC A1B scenario were conclude using the MRI-AGCM3.2S to investigate possible future changes in temperature and precipitation in Ayeyarwady, Myanmar. In the present study (1981-2005) is used as base line period. This research, 16 stations are considered to calculate the temperature and precipitation change. The bias correction was performed using two different techniques, linear scaling and lumped quantile mapping. The temporal variation in the speed of monthly temperature and precipitation differences per month, is quantified by coefficient of determination (R^2) and Root Mean Square Error (RMSE). Bias correction techniques were capable in improving the R^2 value reproduced with GCM outputs.

6. CONCLUSIONS

Lumped quantile mapping bias correction method performs well in simulating future precipitation and temperature changes in the Ayeyarwady Delta, Myanmar. It is observed that the average annual temperature and precipitation trends are projected and they increase for all regions under both scenarios during 21st century. The changes in average annual temperature in Ayeyarwady Delta is projected to increase about 0.7°C and 2.4°C in Ayeyarwady region, about 0.2°C and 1.9°C in Bago region and about 1.1°C and 2.8°C in Yangon region under SRES-A1B scenario for the near future and far future. The changes in average annual precipitation of sixteen stations in Ayeyarwady Delta is projected to increase about 12% and 13% in Ayeyarwady region, about 16% and 19% in Bago region, about 8% and 9% in Yangon region under SRES-A1B scenario at the end of 21st century. Based on this future climate results, we can predict river discharge, crop water requirement, water demand for hydropower, and other necessaries.

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