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Analyzing Rainfall Regimes in Port-Harcourt Metropolis using the Downscaling Techniques

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Abstract: ***Over the years studies have shown that Climate can alter the operations of basic systems in our environment. Furthermore, the African sub region has been identified in the literature to be one of the regions that will suffer most in the coming decades. This study therefore analyzes rainfall regimes in Port-Harcourt metropolis using the downscaling techniques. Ex-post-facto research design was adopted for this study. Data for large scale predictors (1960-2099) were collected from the archive of NCEP, while Predict and data was sourced from NIMET, and for the period 1987-2016. Data analyses were archived through SDSM and ANOVA. However what was established in the study include that, the HadCM3 is applicable to Rainfall downscaling in Nigeria's Niger Delta region; the rainfall amount for the two scenarios have consistently been on the increase; and finally, A2 scenario projected more rainfall amounts that the B2 scenario. The future precipitation will grow more erratic and with some uncertainties; although the trends of rainfall shows that rainfall is on the increase in the area. There is therefore need to adopt a climate plan cum strategy and a coping capacity built, with which to cope with vagaries of rainfall in the coming years.***

Keywords: downscaling, regime, rainfall, metropolis

1. Introduction

Over the years studies (Osman et al., 2014; Al-Rijabo and Salih, 2013; Bilal et al., 2013) have shown that Climate can alter the operations of basic systems in our environment. Furthermore, the African sub region has been identified in the literature (Afa, 2010; Akinyemi & Adejuwon, 2008) to be one of the regions that will suffer most in the coming decades from the pangs of climate change (Al-Rijabo and Salih, 2013; Bilal et al., 2013; Zakaria et al., 2013; Osman et al., 2014; Azooz and Talal, 2015). This is because the level of technological advancement is still very low and crude, hence dependence of socio-economic activities on climate is high- particularly agriculture (Nwagbara et al., 2016) and this has a strong implication on food security cum economic development.

Evidence of greenhouse gas (GHG) increase and positive radiative forcing due to anthropogenic influence has been recorded as one of the substantial drivers of the changes in the climate system and is purported to have resulted in earth's warming, ranging between 0.5°C -1.3°C within the industrial revolution era and now. As such if such anthropogenic activities are allowed to continue unabated, emission rates of GHG will cause further warming and will affect the climate system, (IPCC, 2010). Some of the environmental changes to be expected include flooding, drought, extreme temperature and rainfall events.

Nevertheless, temperature and precipitation constitute the main climate elements that ultimately stimulate the hydro-logic cycle when monitoring climate change. Global Climate Models (GCMs), helps in explaining the changes in climate elements regime and hence the change in climate. Nonetheless, the scales at which these GCMs are built are too coarse; as such they cannot explain some intricate aspects of the climate elements. Therefore, for climate change impact studies, and to resolve the issues inherent of the coarseness of the scale of the GCMs, downscaling is recommended (Ozabor and Nwagbara, 2018; Weli et al., 2017). Downscaling has emerged as a tool for to resolve the misfits in the GCMs and forecast some future regimes of climate element using some emissions scenarios.

More recently, the changing patterns of rain in Port-Harcourt suggest the need to investigate the regimes and explain the possible future outcome using the A2 and B2 scenarios; and there is no better tool to use but statistical downscaling. The study thus applies the statistical downscaling techniques to analyse the rainfall regimes in port-Harcourt.

2. Materials and Methods

The area where this study was carried out is Port Harcourt, and is found on longitude 6˚56'E and 7˚03'E of the Greenwich meridian and latitude 4˚43'N and 4˚54'N of the equator. The area is bordered to the North by Obio/Akpor Local Government area, to the South by Okrika, to the East by Eleme and to the West by Degema Tour Local Government Areas (Farzaneh, 2012; Akinyemi & Adejuwon, 2008). The area is drained by Bonny River and with average elevation of 16 meters AS-level (Afa, 2010; Nwankwoala, 2011). Port-Harcourt is a tropical environment characterised by the tropical monsoon climate with high temperatures, low pressure and high relative humidity all year round. Rain is also experienced all year round and in recent decades the amounts of rains have been so high and have exacerbated the flood events across the metropolis. The weather of the area among other local forcing is influenced by mT and cT airmasses (Weli & Worlu, 2011; Weli et al, 2017; Obinna et al., 2010; Farzaneh, 2012).

The study adopted the expostfacto research design to operationalize the study. Therefore secondary data for large scale predictors (See table 1) covering the period 1960-2099 were collected from the archive of the National Centre for Environmental protection and accessed form the following website; http://www.sdsm.org.uk.

Table 1: List of NCEP predictors used in the screening process

S.No	Predictor Code	Description
1.	p_f	Surface airflow strength
2	p_u	Surface zonal velocity
3	p_v	Surface meridional velocity
4	p_z	Surface vorticity
5	p_th	Surface wind direction
6	p_zh	Surface divergence
7	rhum	Surface relative humidity
8	p5_f	500 hPa airflow strength
9	p5_u	500 hPa zonal velocity
10	p5_v	500 hPa meridional velocity
11	p5_z	500 hPa vorticity
12	p5th	500 hPa wind direction
13	p5zh	500 hPa divergence
14	r500	500 hPa relative humidity
15	p8_f	850 hPa airflow strength
16	p8_u	850 hPa zonal velocity
17	p8_v	850 hPa meridional velocity
18	p8_z	850 hPa vorticity
19	p8th	850 hPa wind direction
20	p8zh	850 hPa divergence
21	r850	850 hPa relative humidity
22	p500	500 hPa geopotential height
23	P850	850 hPa geopotential height
24	temp	Mean temperature at 2m
25	shum	Surface-specific humidity
26	mslp	Mean sea level pressure

Source: NCEP Archives 2017

On the other hand, rainfall data (Predictand) was collected from the archive of Nigerian meteorological agency (NIMET), and for a period of 30years (1987-2016). Sampling technique was purposive due to the fact that, the rates of rainfall influenced inundations over the past decades in the study area have been unparalleled in the whole of the delta. Secondly, the rates of anthropogenic activities in the study area is quite higher than is the case elsewhere in the Niger Delta region of Nigeria. It is thought that the scenarios upon which the HadCM3 model is based can be expressed better at the region. However, analyses were done in two ways. The first was via the SDSM and the other Analysis of Variance (ANOVA) operationalized in the environment of the SPSS (statistical packages for the social sciences).

In the SDSM environment, depending on the predictand being downscaled the following steps are required for the downscaling process to be appropriate: Quality control, Screen variables, Model calibration, Weather generator and Scenario generator

Quality control: in this study the data was fed into the SDSM software to find out if there were any missing data set within the data array

Screen variables: the variables were screened to see the predictors that performed well with the predictand. In the case of this study, the correlation values and p values were used (see table 2), in which case the selected predictors are Shum, Rhum, r850, and r500.

Table 2: Rainfall Predictors for Port-Harcourt

Predictors	N	R	P value at 0.05
Shum	10950	0.693	0.00, significant at P<0.05
Rhum	10950	0.704	0.00, significant at P<0.05
R850	10950	0.772	0.00, significant at P<0.05
R500	10950	0.680	0.00, significant at P<0.05

Predictors: shum, rhum, r850, r500

Model calibration: calibration was achieved in this study by finding a regression coefficient between the predictand and the predictors (see table 3)

Table 3: calibration result for Port-Harcourt

Months	R^2	SE	Durbin-watson
January	0.61	2.122	0.231
February	0.62	2.231	1.631
March	0.72	1.207	1.931
April	0.71	1.023	1.231
May	0.54	1.241	1.451
June	0.70	2.112	1.921
July	0.63	3.521	1.234
August	0.57	2.411	2.251
September	0.62	2.223	2.252
October	0.60	3.201	1.921
November	0.71	2.871	1.732
December	0.65	1.709	1.239

Predictors: ncepp_Shum, ncepp_rhum, ncepp_r850, ncepp_r500

Validation: this was achieved computing the regression coefficient between the observed and the modelled data, finding out the coefficients of determination and the computing the root mean square error and the ratio of standard deviation between the observed and modelled data. However these computations were done on a seasonal scale (see table 4)

Table 4: Validation of SDSM for seasonal rainfall predictions

Station	Scale of SDSM	Rainfall seasons	R	r^2	RMSE	RSD	P value at 0.05
Porthar court	Seasonal	DJF	0.64	0.41	0.42	0.88	0
		MAM	0.75	0.56	0.41	1	0
		JJA	0.86	0.74	0.23	1.02	0
		SON	0.91	0.83	0.11	1.11	0

***R**- stand for correlation coefficient between simulated and observed data; **r^2**- coefficient of determination; **RMSE**- root mean square error, **RSD**- ratio of standard deviation 0.05 P value – alpha for significance between simulated and observed data set.*

Scenario generator: the modelled data set was then used to generate what the possible outcomes of rainfall amounts will be in the different scenarios.

Thereafter, the ANOVA analyses were performed on the downscaled out puts of the different scenarios to find out the inherent variations in the normals downscaled. This was achieved via the SPSS software.

3. Results and Discussions

Screening of predictors is the most important process in all types of statistical downscaling (Wilby *et al.*, 2002; Huang *et al*., 2011).The main reason for screening of appropriate downscaling predictor variables is for the identification of large-scale predictor variables (NCEP) which are sufficiently significant in terms of correlation with the observed station (predictand) data. In the present study, like every other SDSM, various indicators like correlation, explained variance, P-value, as already used by (Mahmood and Babel, 2014) with great success was applied to select suitable predictors for the station leaving no chance to multiple co-linearity between the predictor variables. Thus the best sets of predictors with good correlation were selected as shortlisted in the table. All the predictors registered in the table were selected after the screening exercise because they all had a better coefficient and were all significant at P<0.05 and they are surface specific humidity (r, 0.69=P<0.05), Near surface relative humidity (r, 0.70=P<0.05), Relative humidity at 850hpa (r, 0.77=P<0.05) and Relative humidity at 500hpa (r, 0.68=P<0.05).

From the record revealed in table 2, it is obvious that rainfall in Port Harcourt is strongly influenced by four major predictors which are basically humidity related variable and they are surface specific humidity, Near surface relative humidity, Relative humidity at 850hpa, Relative humidity at 500hpa. Though their level of significance falls within a close range and are all significant at <0.05. Nevertheless, r500 is the least significant with r, 0.68=P<0.05, while shum and rhum has (r, 0.69=P<0.05, r, 0.70=P<0.05) respectively, whereas Relative humidity at 850hpa with (r, 0.77=P<0.05 is the most significant among all the predictors.

During calibration the model sufficiently establishes that predictors of rainfall in Port Harcourt are r850, r500, rhum, and shum (see table 3). The table also confirms that the model is significant at p<0.05, hence, it is concluded that rainfall in Port Harcourt is significantly dependent on r850, r500, rhum, shum as the most suitable predictors. The validation result in the study area shows that (DJF) seasonal sub-model for rainfall are captured r- 0.64, r^2- 0.41, RMSE- 0.42, RSD- 0.88 and p<0.05. Also Port Harcourt (MAM) seasonal sub-model for rainfall for the same station are practically presented r- 0.75, r^2- 0.56, RMSE- 0.41, RSD- 1.00 and p<0.05. The table also account for Port Harcourt (JJA) seasonal sub-model for rainfall which are r- 0.86, r^2- 0.74, RMSE- 0.23, RSD- 1.02 and <0.05 and Port Harcourt (SON) seasonal sub-model for rainfall revealed r- 0.91, r^2- 0.83, RMSE- 0.11, RSD- 1.11 and p<0.05. Consequently, the table revealed that there is a significant relationship between the simulated and observed data for the period of validation (2001-2016) in the different seasons in Port Harcourt. This implies that the model has high predictive ability, due to the R and RMSE values. It can therefore be logically concluded that the H_o hypothesis for Port Harcourt which states that there is no statistical significant relationship between the simulated and observed (SDSM/HadCm3) data be rejected and the alternate becomes the explanation at p<0.05 that there is a significant relationship between the simulated and observed data for Port Harcourt. Hence, the predictand can be downscaled for that station.

In Table 5, the uncertainty information of the projections made by the model based on the observation period at Port Harcourt station is displayed. In the table the observed and simulated data is paired and the hypothesis which states that, 'there is no significant difference between the simulated and observed data is tested to verify if there are uncertainties. On the other hand, if any significant difference exists between the simulated and observed data, it implies that there are some uncertainties that may be peculiar to that particular station. However, in table 5, uncertainties exists in the months of October at p<0.05 (0.006) and April under the A2 scenario at p<0.05 (0.023) and in the month of December under the B2 scenario at p<0.05 (0.039).

The p-values are above 0.05 for all months except for these months, October, April and December under scenarios A2 and B2 respectively. This finding reveals that the null hypothesis was not rejected; suggesting that observed and SDSM simulated estimates were statistically similar for every month except October, April and December. For these months, the null hypothesis was rejected because the p-values were below the critical value of 0.05. This implies that the prediction is true for Port Harcourt station and at 95% confidence level for all other months except for October, April and December. This also reveals that the accuracy of the model's prediction for the months of October, April and December under scenarios A2 and B2 respectively is not guaranteed as it may not capture the true situation. Hence projections results for those months within the projected period need to be used with absolute caution.

Table 5: Rainfall uncertainty analysis for Port-Harcourt

Months	HadCM3	A2 scenario	B2 Scenario
January	1.121	0.102	0.231
February	0.362	0.231	1.231
March	2.210	1.207	0.991
April	0.171	0.023	1.231
May	0.341	0.241	0.451
June	0.211	0.112	0.921
July	0.231	0.521	0.234
August	0.351	2.411	0.251
September	0.122	0.123	0.052
October	0.006	0.501	0.921
November	0.231	2.871	0.712
December	1.102	0.769	0.039

Table 6: Temporal variation in mean rainfall of Port Harcourt under A2 scenario

ANOVA					
Port Harcourt_RF					
	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	23978.070	2	9767.005	147.020	.000
Within Groups	24676377.616	1077	36553.055		
Total	24700356.690	1079			

In table 6, the ANOVA statistics applied disclose the temporal variation in mean rainfall for Port Harcourt under the A2 scenario and it is significant at p<0.05 (147.0) which specifies that there is a significant difference in monthly rainfall over time in Port Harcourt. The value of F (147.0) suggests that the variation in rainfall over time in Port Harcourt do not just happen by chance. Therefore the null hypothesis that, there is no significant difference in monthly rainfall mean is rejected; which implies that the alternate hypothesis becomes the explanation to the situation that there is a significant difference in monthly rainfall mean in Port Harcourt. Consequently, to identify where the said difference in monthly rainfall means lies in Port Harcourt, it is important to give attention to table 7. In the table it is sufficiently clear that Port Harcourt continuously experience drastic change in rainfall conditions. While the 1960-1989 period shows the mean monthly rainfall of the area as 172.7mm, the mean monthly rainfall of the 1990-2019 normal stands at 191.5mm. This put the change at 18.8mm and this change between the first and next climate normal reveals a null relationship at $p<0.05$. The normal 2020-2049 has a mean of 219.9mm which shows a difference of 28.4mm. This change of 28.4mm between the two normal also shows a null relationship at p<0.0.5. This gradual change and rise in rainfall means is a clear explanation of the fact that the rainfall of the area has shown significant rise since 1960 and on this ground this continuous rise and change in rainfall conditions is here projected to continue under the A2 scenario. This implies that the period 2020-2049 will be wetter than the two other epochs. On the other hand, the table reveals that the lowest rainfall amount was captured in the period 1960-1989.

Table 7: Duncan statistics of Port Harcourt rainfall under A2 scenario

Port Harcourt_RF				
Duncan[a,b]				
		Subset for alpha = 0.05		
Identifiers	N	1	2	3
1960-1989	360	172.6708		
1990-2019	360		191.4540	
2020-2049	360			219.9113
Sig.		1.00	1.00	1.00
Means for groups in homogeneous subsets are displayed.				
a. Uses Harmonic Mean Sample Size = .1080				

Table 8: Temporal variation in mean rainfall of Port Harcourt under B2 scenario

ANOVA					
Port Harcourt_RF					
	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	23978.070	2	9767.005	6.101	.005
Within Groups	24676377.616	1077	36553.055		
Total	24700356.690	1079			

In table 8, the temporal variation in mean rainfall for Port Harcourt under the B2 scenario established through the use the ANOVA statistics is made known and it is significant at $p<0.05$ (8.1) which reveals that there is a significant difference in monthly rainfall over time in Port Harcourt. The value of F (6.1) implies that the variation in rainfall over time in Port do not just happen by chance. Therefore the null hypothesis that, there is no significant difference in monthly rainfall mean is rejected; which implies that the alternate hypothesis becomes the explanation to the situation that there is a significant difference in monthly rainfall mean in Port Harcourt. Subsequently, to confirm where the expected difference in monthly rainfall means exist in Port Harcourt, it is better to centre on table 9.

Table 9: Duncan statistics of Port Harcourt rainfall under B2 scenario

Port Harcourt_RF				
Duncan[a,b]				
		Subset for alpha = 0.05		
Identifiers	N	1	2	3
1960-1989	360	158.6708		
1990-2019	360		169.0030	
2020-2049	360			185.1551
Sig.		1.00	1.00	1.00
Means for groups in homogeneous subsets are displayed.				
a. Uses Harmonic Mean Sample Size = 1080.				

The prevailing change in rainfall conditions over time is well captured in the table. While the 1960-1989 period shows the mean monthly rainfall of the area as 158.7mm, the mean monthly rainfall of the 1990-2019 normal stands at 169.0mm. This put the change at 10.3mm and this change between the first and next climate normal reveals a null relationship at $p<0.05$. The normal 2020-2049 has a mean of 185.2mm which shows a difference of 16.2mm. This change of 16.2mm between the two normal also shows a null relationship at p<0.0.5. This gradual change and rise in rainfall means is a clear explanation of the fact that the rainfall of the area has shown significant rise since 1960 and on this ground this continuous rise and change in rainfall conditions is here projected to continue under the B2 scenario. This implies that the period 2020-2049 will be wetter than the two other epochs though at a dawdling rate while on the other hand, the lowest rainfall amount was recorded in the period 1960-1989.

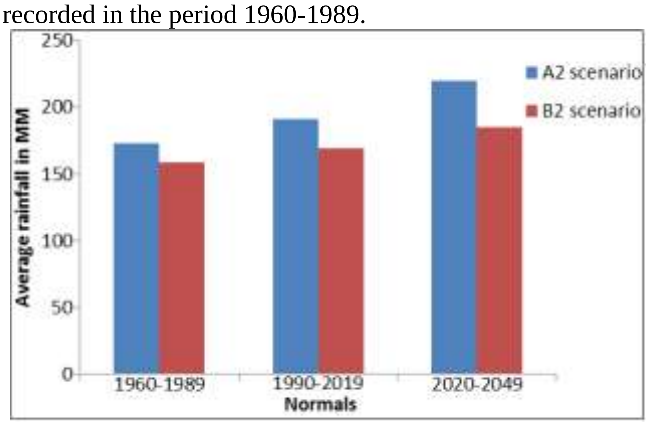

Figure 1: Comparison between the rainfall amounts for A2 and B2 scenarios

Finally in figure one the amount of rainfall modelled for both the A2 and B2 scenarios are displayed. From the table it is clear that the A2 scenario is projected to have more rainfall volumes than the B2 scenario.

4. Recommendation and Conclusion

SDSM was applied in this study to downscale and generate long-term future scenarios of climate predictand (Rainfall) from predictors of HadCM3 models. These future scenarios are generated under A2 and B2 emission scenarios. However what was established in the study include that, the HadCM3 is applicable to Rainfall downscaling in Nigeria's Niger Delta region; the rainfall amount for the two scenarios have consistently been on the increase; and finally, A2 scenario projected more rainfall amounts that the B2 scenarios. The future precipitation will grow more erratic and with some uncertainties; although the trends of rainfall shows that rainfall is on the increase in the area. There is therefore need to adopt a climate plan cum strategy and a coping capacity built with which to cope with vagaries of rainfall in the coming years.

References

[1] Afa, J.T. (2010) Subsoil Temperature and Underground Cable Distribution in Port Harcourt City. *Research Journal of Applied Sciences , Engineering and Technology* ,2, 527- 531.

[2] Akinyemi, F. & Adejuwon, J.O. (2008) A GIS-Based Procedure for Downscaling Climate Data for West Africa. *Transactions in GIS*, 12, 613-631. https://doi.org/10.1111/j.1467-9671.2008.01120.x

[3] Al-Rijabo WI, Salih HM. (2013). Spatial and temporal variation of rainfallin Iraq. J. *Appl. Phys.* 5(4): 01–07.

[4] Azooz AA, Talal SK. (2015). Evidence of climate change in Iraq. *J. Environ. Prot. Sustain. Dev*. 1(2): 66–73.

[5] Bilal DA, Al-jumaily KJ, Habbib EA. (2013). Air temperature trends in Baghdad, Iraq for the period 1941–2000. Int. J. Sci. Res. Publ. 3(9): 1.

[6] Farzaneh, M.R., Eslamian, S., Samadi, S.Z. and Akbarpour, A. (2012) An Appropriate General Circulation Model (GCM) to Investigate Climate Change Impact. *International Journal of Hydrology Science and Technology*, 2, 34-47. https://doi.org/10.1504/IJHST.2012.045938

[7] Nwankwoala, H.O. (2011), An Integrated Approach to Sustainable Groundwater Development and Management in Nigeria. *Journal of Geology and Mining Research*, 3, 123-130.

[8] Nwagbara., M. O., Ozabor., F and Obisesan., A. (2017) Perceived Effects of Climate Variability on Food Crop Agriculture in Uhunmwode Local Government Area of Edo State, Nigeria. *Journal of Scientific Research & Reports*,16(3) Pp 1-8

[9] Obinna, V.C., Owei, O.B. and Mark, I.O. (2010) Informal Settlements of Port Harcourt and Potentials for Planned City Expansion. *Environmental Research Journal* , 4, 222-228. https://doi.org/10.3923/erj.2010.222.228

[10] OsmanY,Al-nasari N, Abdellatif M, Aljawad SB. (2014). Expected future precipitation in central Iraq using LARS-WG stochastic weather generator. *Engineering* (6): 948–959.

[11] Ozabor., F and Nwagbara., M., O. (2018) Identifying Climate Change Signals from Downscaled Temperature Data in Umuahia Metropolis, Abia State, Nigeria. *Journal of Climatology & Weather Forecasting*, 6(1) Pp 1-5

[12] Weli, V.E., Nwagbara., M.O and Ozabor., F (2017) The Minimum and Maximum Temperature Forecast Using Statistical Downscaling Techniques for Port-Harcourt Metropolis, Nigeria. *Atmospheric and Climate Sciences*, 7, Pp424-435

[13] Weli, V.E. and Worlu, S.O. (2011) Recent Rainstorm Dynamics and Its Implications for Flood Frequency in Sub-Humid Tropical City of Port Harcourt, Nigeria. Journal of Geographic Thought , 12, 31-59.

[14] Zakaria S, Al-Ansari N, Knutsson S. 2013. Historical and future climate change scenarios for temperature and rainfall for Iraq. *J. Civil Eng. Archit*. 7(12): 1574–1594.