Doctoral School in Informatics for Climate Change

Climate dynamics, change and predictions 2020 – 2021

Projected Change in Temperature and Precipitation Over West Africa from MIROC6 outputs

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Abstract

In this report, we analyze 4 data (Temperature and Precipitation, both historical and future projection) from MIROC6 model and examine projected changes in temperature and precipitation over West Africa during the twenty-first century. The temperature and precipitation changes are computed for two future time slices, 2030-2059 (near future) and 2070-2099 (future), relative to the historical climate (1981-2010), for the West Africa and its tree regions, Guinea Coast, Savannah and Sahel. The model projected a continuous and significant increase in the mean annual temperature over the entire West Africa. By the end of the century, possible warming over West Africa ranges from 0.3 °C to 5.1 °C with the Sahel experiencing the largest changes, while the smallest rise over Guinea Coast, under the Shared Socioeconomic Pathways (SSP5-8.5) for strong forcing. On the other hand, projected precipitation over West Africa is highly uncertain, but climate change causes more precipitation variability with greater amplitudes. Generally, the result indicates that the Savannah has experienced wetter conditions while the small part of the Guinea Coast has recorded dried conditions under the SSP5-8.5.

Keywords West Africa – Precipitation – Temperature – MIROC6 – Future projection

1- Introduction

Africa, the second most populous continent in the world, is one of the regions most vulnerable to climate change due to its high exposure and low adaptive capacity (Sutton et al. 2011; Barros et al. 2014). Previous studies (eg. Christy et al. 2009; Jones and Moberg 2003; Kruger and Shongwe 2004; Mohamed 2011; Nicholson et al. 2013; Stern et al. 2011; Trenberth 2007) have reported a rise in observed near-surface temperature over most of Africa of approx. 0.5 °C during the past 50-100 years. Collins (2011) found a significant increase in the near-surface temperature anomalies over Africa in recent years (1995-2010) as compared with 1979-1994. Due to its large latitudinal extent, the climate of the Africa continent varies widely. New et al. (2006) found fewer cold days and cold nights and more warm days and warm nights over West Africa during the period 1961-2006. The risk of deadly heat stress waves is likely to increase over West Africa, while heat waves are likely to be more frequent and longer under the effect of global warming (Diedhiou et al. 2018; Sylla et al. 2018).

On the other hand, precipitation over the African continent is highly variable. Available observational data sets show large discrepancies over Africa (Kruger and Ahongwe 2004; Nikulin et al. 2012; Kalognomou et al. 2013; Sylla et al. 2013), and therefore it is difficult to draw robust conclusions about precipitation trends during the past century.

Future climate projections over Africa for the twenty-first century indicate that its land temperature will rise faster than the global mean temperature, particularly in the more arid regions (Niang et al. 2015). Precipitation projections are more uncertain than temperature projections and display larger spatial variability and seasonal dependence (Orlowsky and Seneviratne 2012). The present study, aims to examine the projected changes in future temperature and precipitation over West Africa using MIROC6 dataset. The report further describes projected annual mean changes in temperature and precipitation over tree West African subregions, Guinea Coast, Savannah and Sahel.

2- Data and Methodology

For this work, 4 monthly datasets from MIROC6 are provided by the Lecturer, Dr. Vincent Ajayi. These are precipitation and temperature datasets, both historical (1951-2014) and model projection (2015-2099), under SSP5-8.5. In addition, ***Projected Change in Temperature and Precipitation Over Africa CMIP6*** (Almazaroui et al. 2020) article is given as inspiration document. We re-gridded the datasets to cover West Africa (20W-20E, 0-20N). All calculations have been done with “cdo” commands and the plotting with “ferret” software commands.
First, temperature data and precipitation data were analyzed to depict temperature and precipitation climatology over West Africa for the period 1981-2010. The same has been done with projected data for the period 2030- 259 considered as near future and the period 2070-2099 considered as future. In a second step, we analyzed and examined future changes in temperature and precipitation from differences from 2030-2059 minus 1981-2010, in one side and 2070-2099 minus 1981-2010, in other side. Lastly temperature and precipitation trends were examined for a continuous period from 2030 to 2099 over Guinea Coast, Savannah and Sahel.

3- Results and Discussion

3-1 Observed Climatology and Climate Models' Evaluation

3-1-1 Temperature

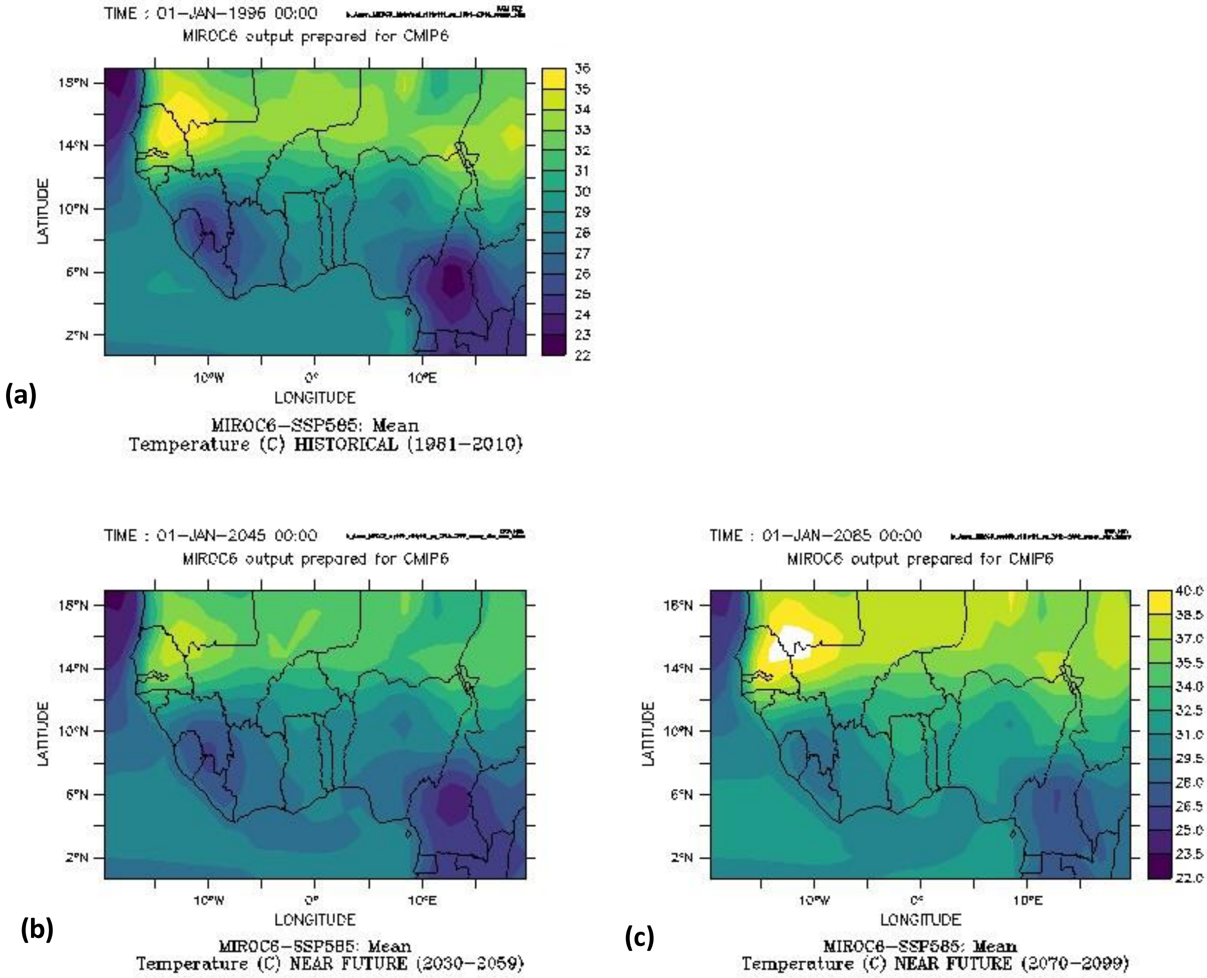

Fig 1: Observed mean annual temperature (°C) climatology over West Africa for the period 1981-2010 **(a)**, the period 2030-2059 **(b)** and the period 2070-2099 **(c)**.

The observed mean annual temperature over West Africa during the period 1981-2010 is shown in the figure above (**Fig 1a**). The mean annual temperature varies from 22 °C to 36 °C. The lowest values (< 22 °C) occur over Guinea, Sierra Leone, Liberia and one part of Cameroon. The highest values (> 36 °C) occur in the western part of Sahel.

Fig 1b and **c** displays the performance of the model in the simulation of mean annual temperature over West Africa in the present climate with respect to the observations. Regarding this figure, the global warming mostly represented by the yellow color (> 37 °C) is more significant in **Fig 1c**. The western part of Sahel experienced the largest value (40 °C).

3-1-2 Precipitation

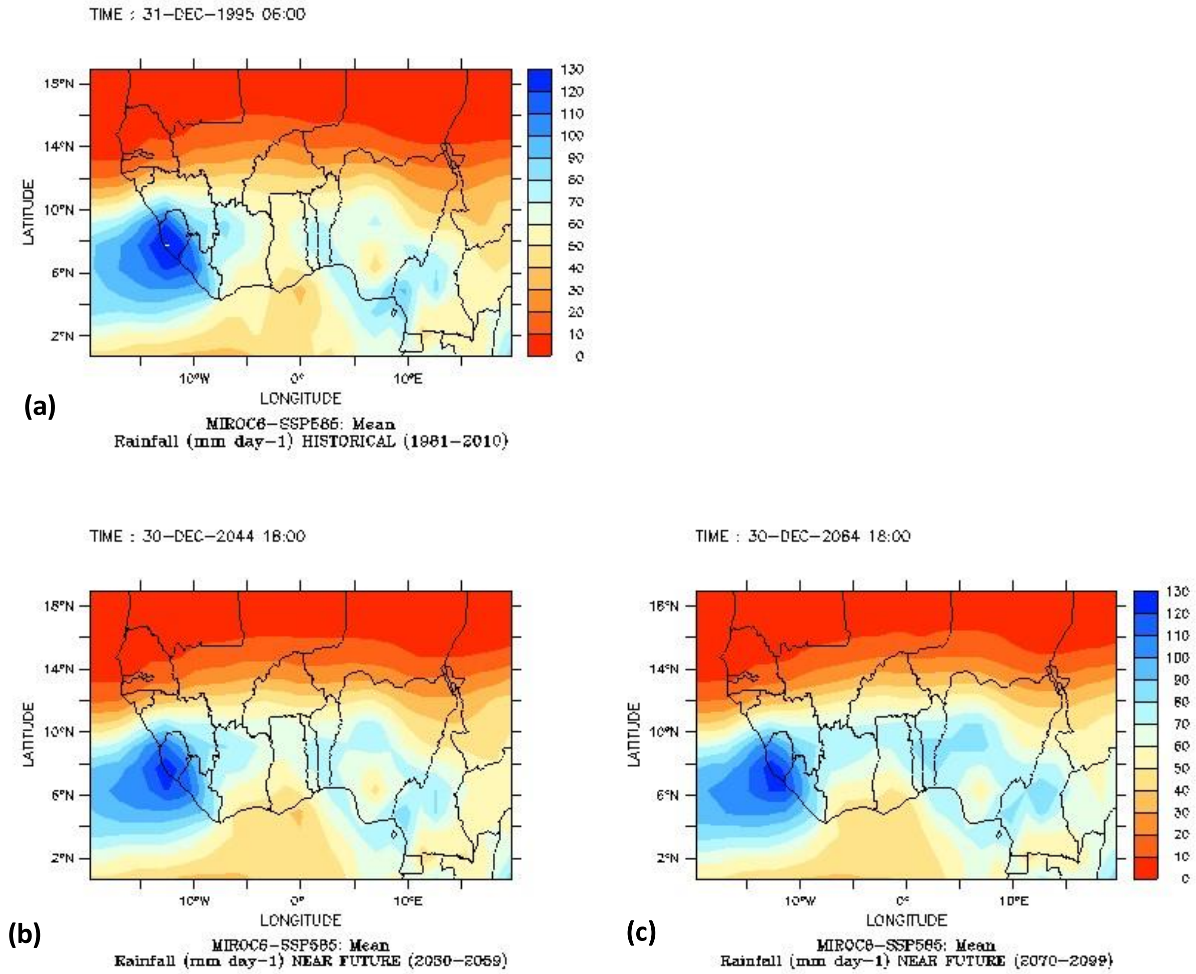

Fig 2: Observed mean annual precipitation (mm per day) climatology over West Africa for the period 1981-2010 **(a)**, the period 2030-2059 **(b)** and the period 2070-2099 **(c)**.

The observed mean annual precipitation over West Africa during the period 1981-2010 is shown in the figure above (**Fig 2a**). Unlike temperature, precipitation over West Africa is highly variable and ranges from 0 mm per day to 130 mm per day. Most of the mean annual precipitation over West Africa during 1981-2010 occurred over Guinea, Sierra Leone, Liberia (100 – 130 mm per day). The smallest amount of precipitation occurs in Sahel (0 – 20 mm per day).

Fig 2b and **c** displays the performance of the model in the simulation of mean annual precipitation over West Africa in the present climate with respect to the observations. Compared to the historical mean annual precipitation, the projected precipitation is highly uncertain, however, it can be noticed a small decrease in rainfall over Guinea.

3-2 Change in Mean Annual Temperature and Precipitation Projections Over West Africa

3-2-1 Temperature

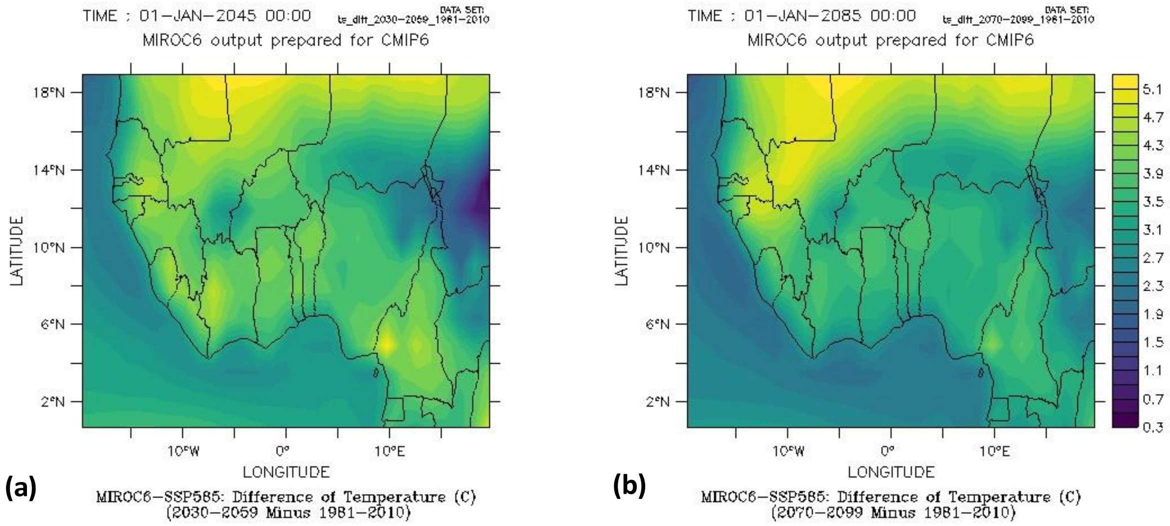

Fig 3: Future changes in mean annual temperature (°C) over West Africa for the two time periods 2030-2059 **(a)** and 2070-2099 **(b)** as compared with the reference period 1981-2010.

The figure above shows the projected changes in mean annual temperature over West Africa. The future temperature projections indicate enhanced warming over West Africa, during both 2030-2059 and 2070-2099 periods during the twenty-first century relative to the reference climate (1981-2010), under the SSP5-8.5. The warming increases toward the end of the twenty-first century, and the most rapid increasing occurs during 2030-2059 period, where all West African subregions experienced the warming. During 2070-2099 period, the western part of Sahel experienced the largest changes. By the end of the twenty-first century, possible warming over West Africa ranges from 0.3 °C to 5.1 °C, under the high-emission SSP5-8.5.

3-2-2 Precipitation

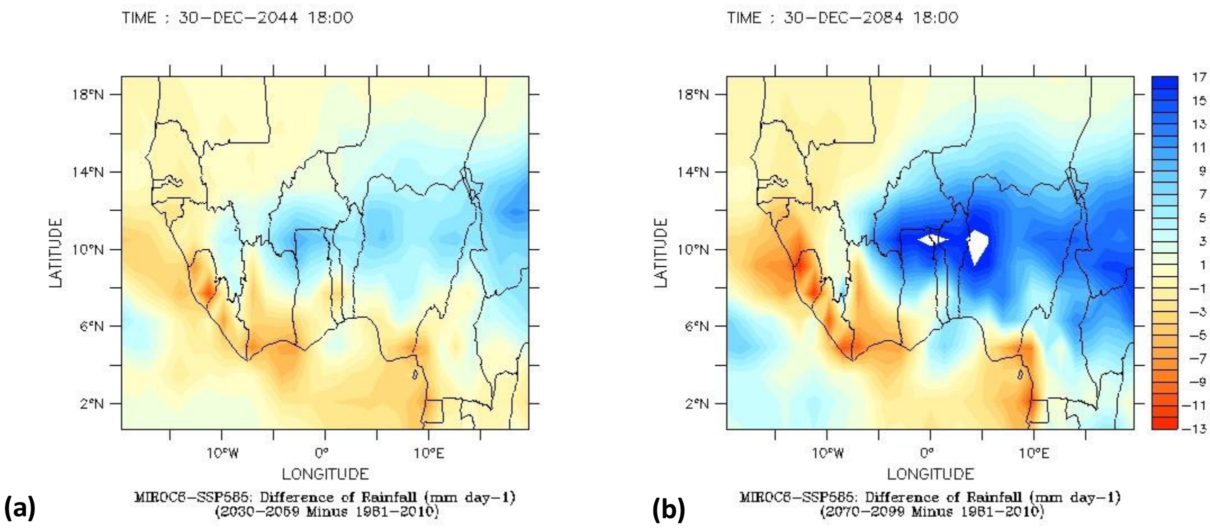

Fig 4: Future changes in mean annual rainfall (mm/day) over West Africa for the two time periods 2030-2059 **(a)** and 2070-2099 **(b)** as compared with the reference period 1981-2010.

The projected changes in precipitation over West Africa under the SSP5-8.5 scenario for 2030-2059 and 2070-2099 periods are shown in the figure above (**fig 4**.). Generally, the precipitation is rising in some area and decreasing in others. The changing is slow during 2030-2059 period and more rapidly during 2070-2099 period. The highest levels of an increasing rainfall occur in countries such as Nigeria, Burkina Faso, northern part of Ghana, Togo and Benin. On the other hand, the highest levels of decreasing rainfall occur over Guinea, Liberia and Sierra Leone. By the end of the twenty-first century, changes in precipitation over West Africa ranges from -13 (mm per day) to 17 (mm per day), under the high-emission SSP5-8.5.

4- Future temperature and precipitation trends over West Africa

- Temperature

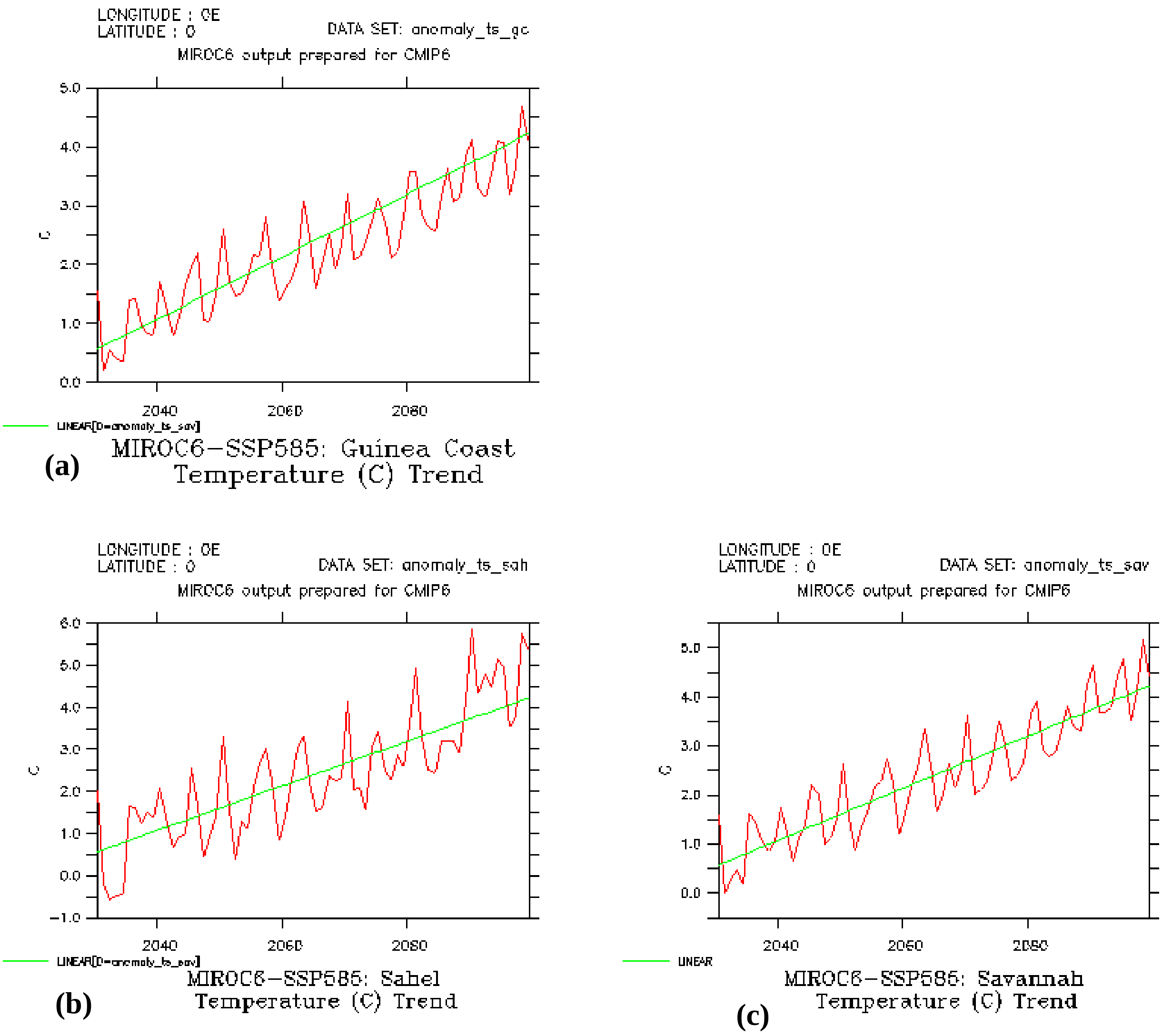

Fig 5: Temperature (°C) trends over West Africa **(a)** Guinea Coast, **(b)** Sahel and **(c)** Savannah. The curves are obtained by taking the difference of each future year with respect to the average from historical period 1981-2010 (Anomalies).

- **Precipitation**

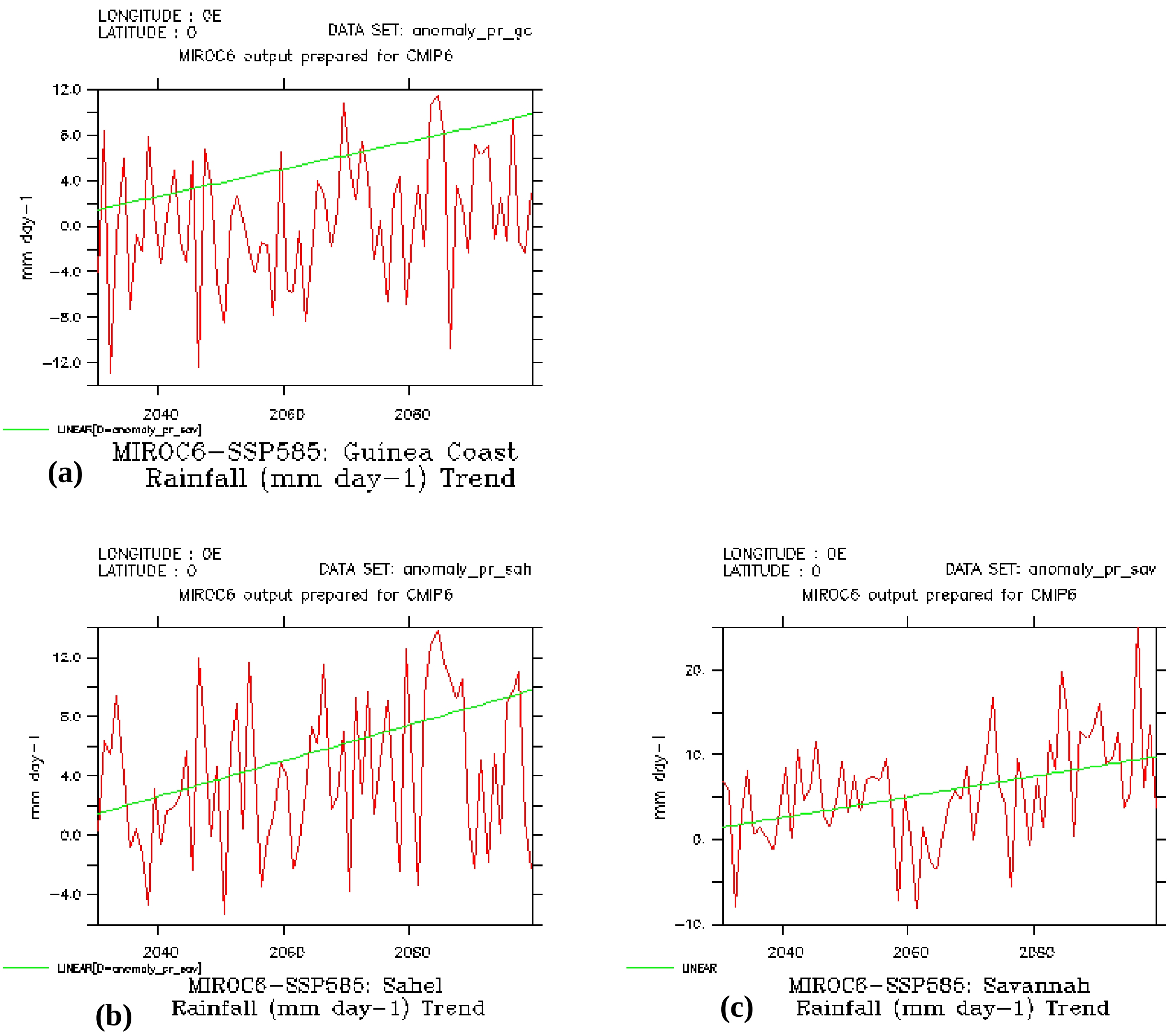

Fig 6: Precipitation (mm per day) trends over West Africa **(a)** Guinea Coast, **(b)** Sahel and **(c)** Savannah. The curves are obtained by taking the difference of each future year with respect to the average from historical period (1981-2010).

4.1 Guinea Coast

Temperature trend over Guinea Coast is shown at **Fig 5.a** and the precipitation at **Fig 6.a.** The **Fig 5.a** shows continuous warming during the twenty-first century. The increasing trend in temperature over Guinea Coast under SSP5-8.5 is projected to be ranged from 0.25 °C to 4.75 °C. For precipitation, **Fig 6.a** shows a large ensemble spread as well as interannual variability with no clear trend. The projected changes in precipitation under SSP5-8.5 ranges from -13 to 11.85 (mm per day).

4.2 Savannah

Fig 5.c shows temperature trend over Savannah during the twenty-first century while **Fig 6.c** shows precipitation trend. The increasing trend in temperature, under the SSP5-8.5 shown by the **Fig 5.c** is projected to be ranged from 0 °C to 5.1 °C. On the other hand changes in precipitation is projected to range from -7.5 to 25 mm per day as shows **Fig 6. c**. Generally the trend indicates that there will be an increase of precipitation over Savannah, by the end of twenty-first century.

4.3 Sahel

Temperature trend over Sahel is shown at **Fig 5.b** and the precipitation at **Fig 6.b.** The **Fig 5.b** shows continuous warming during the twenty-first century. The increasing trend in temperature over Sahel under SSP5-8.5 is projected to be ranged from -0.6 °C to 5.9 °C. For the changes in precipitation, the region is projected to experience strong interannual variability as shown in **Fig 6. b**. The projected changes in precipitation range from -6 to 14 mm per day.

5- Conclusion

In this report, we analyzed MIROC6 precipitation and temperature data and examined projected temperature and precipitation changes over West Africa in the twenty-first century. These changes were computed during two future time slices 2030-2059 and 2070-2099 relative to the historical climate from 1981-2010. The model projected a continuous increase in annual mean temperature over the entire West Africa with the western part of Sahel experienced the largest changes, under the high emission scenario SSP5-8.5. On the other hand, projected precipitation over West Africa shows high precipitation variability with associated uncertainty in mean annual changes.

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