RAINFALL AND TEMPERATURE CHARACTERISTIC OVER ZAMBIA

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ABSTRACT

Temperature and rainfall are important elements of climate Zambia where several sectors of the economy depend mostly on water resources. Zambia normally receives the bulk of its annual rainfall from November to March (NDJFM) as the ITCZ moves south and experience high temperatures. The major objective of the study was to investigate the rainfall and temperature characteristic over Zambia.

To achieve the objectives of this study, two distinct datasets were utilized which include; gridded Rainfall data from the National Center for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) reanalysis datasets and the Pressure Temperature data, (NOAA/NCEP). Empirical Orthogonal Functions (EOF) analysis and trend analysis methods were used in the study.

The results show that the annual cycle rainfall of Zambia depict one rainy season which lies between November and March (NDJFM) over the region, with the average rainfall in summer around 200mm.whereas the annual cycle of temperature over Zambia indicates that temperatures are higher in the region between Septembers to March, which is in part associated with rainy season (NDJFM) over the region. The low temperatures are observed during June and July. The rainfall climatology of NDJFM reveals that there is more rainfall received in the northern region compared to the rest of the country which is opposite with temperature climatology of NDJFM. In general however, there is a decreasing trend of rainfall in the region (red line), with a rate of decrease of 0.0062 (indicated as -0.0062) mm per year. The interannual variability of NDJFM seasonal temperature indicates that temperature has been varying with higher frequency of cold events between 1960- 1985. After this period, warm events (above normal temperature) dominated. In general however, there is an increasing trend of temperature in the region (red line), with a rate of increase of 0.036oC per year. The dominant mode of variability for both temperatures and rainfall exhibits single modes of variability with positive loadings for the entire region.

Keywords: Rainfall variability and temperature.

1.0 INTRODUCTION

Zambia is vulnerable to changes in water availability, since its precipitation shows high temporal and spatial variability on a wide range of scales. As a result, the large rural population of the country, who mainly depend on rain-fed agriculture, is greatly influenced by regional climate variability. Rainfall is the most important climate variable over Zambia, where several sectors of the economy depend mostly on water resources. Its variability and predictability is therefore an important aspect to address in climate research over the region. The year in Zambia can be divided into two distinct halves, a dry half from May to October and a wet half from November to April when the Inter-tropical Convergence Zone (ITCZ) is located in the Zambian region. So we can say the region has two distinct season dry and wet season. Rainfall in Zambia is strongly (ITCZ). The ITCZ changes position during the year, moving between the equator and the tropics of cancer and Capricorn. Zambia normally receives the bulk of its annual rainfall from November to March (NDJFM**)** as the ITCZ moves south.

Africa as a whole is considered highly vulnerable to climate change (FAO, 2004), largely because many socio-economic activities in Africa, particularly agriculture, depend on climate parameters, more especially rainfall. Precipitation and temperature being the most important meteorological parameters in Zambia has directly influenced the socio-economic activities and the poor rural population because of their dependence on natural resources; manifest the largest susceptibility (World Bank, 1996). Consequently, climate variations and change have an impact on the productivity of many socio-economic activities (Obasi, 2005). Within the agricultural sector, drought is arguably the most important climatic challenge and has major impacts on rural livelihoods (Buckland et al., 2000). Furthermore, projections of future change place Zambia's agriculture sector at the forefront of climate change vulnerability with potential negative impacts on revenue from dry land farming (Kurukulasuriya et al., 2006).

1.1 Objectives of the Study

The major objective of the study is to investigate rainfall and temperature characteristics over Zambia.

Specific Objectives:

(i) To investigate the spatial and temporal characteristics of seasonal (NDJFM) rainfall over Zambia.

(ii) To investigate the spatial and temporal characteristics of seasonal (NDJFM) temperature over Zambia.

(iii) To investigate the rainfall and temperature trends over Zambia.

2.0 Study Area

Zambia is a landlocked country in southern Africa, with a tropical climate and consists mostly of high plateau, with some hills and mountains, dissected by river valleys. The country lies mostly between latitudes 8° and 18°S, and longitudes 22° and 34°E. Zambia is divided into ten provinces; each province is subdivided into several districts with a grand total of 73 districts.

MAP OF AFRICA

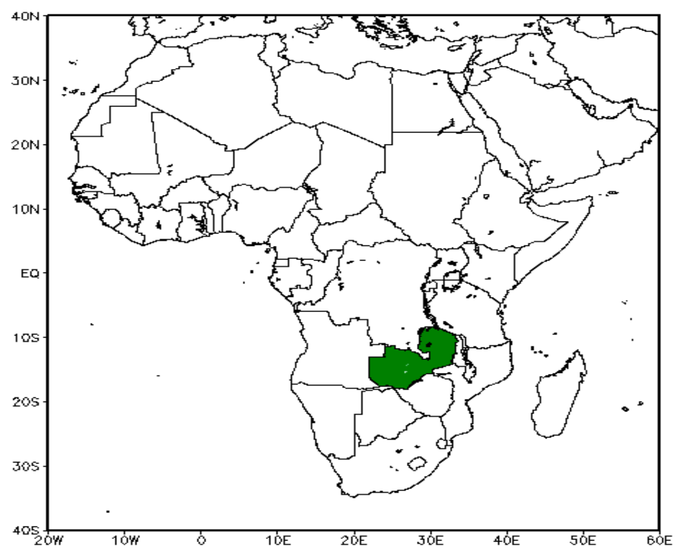


Figure 1: Shows the study area (Zambia), marked green on the map of Africa.

2.1 Climate of Zambia

The climate of Zambia is tropical modified by elevation. In the Köppen climate classification, most of the country is classified as humid subtropical or tropical wet and dry, with small stretches of semi-arid steppe climate in the south-west and along the Zambezi valley. There are two main seasons, the rainy season (November to April) corresponding to summer, and the dry season (May/June to October/November), corresponding to winter. The dry season is subdivided into the cool dry season (May/June to August), and the hot dry season (September to October/November). The modifying influence of altitude gives the country pleasant subtropical weather rather than tropical conditions during the cool season of May to August. However, average monthly temperatures remain above 20 °C (68 °F) over most of the country for eight or more months of the year. Rainfall varies over a range of 500 to 1,400 mm (19.7 to 55.1 in) per year (most areas fall into the range 700 to 1,200 mm or 27.6 to 47.2 in). The distinction between rainy and dry seasons is marked, with no rain at all falling in June, July and August. Much of the economic, cultural and social life of the country is dominated by the onset and end of the rainy season, and the amount of rain it brings. Failure of the rains causes hunger from time to time.

The average temperature in Zambia in the summer is 30°C and in the winter (colder season) it can get as low as 5°C. The rains are mainly brought by the Intertropical Convergence Zone (ITCZ) and are characterised by thunderstorms, occasionally severe, with much lightning. The ITCZ is located north of Zambia in the dry season. It moves southwards in the second half of the year, and northwards in the first half of the year. The highest rainfall is in the north, especially the north-west and the north-east, decreasing towards the south; the driest areas are in the far south west and the Luangwa River and middle Zambezi River valleys, parts of which are considered semi-arid. None of the country is considered arid or to be desert.

Flooding is an annual event on floodplains, to which people and wildlife are adapted. Flash floods after unusually heavy rain cause damage when they occur in places that do not experience annual floods. Erosion and the washing out of roads and bridges are common. Crops are frequently damaged by flooding and hail. Too much rain when the maize crop is flowering, or late in the season when it should be drying off prior to harvest, can be very damaging and promotes rotting of stored grain.

3.0 Data and Methodology

This chapter provides the datasets and the methods used in the analyses to meet the study objectives.

3.1 The Datasets That Is Used Include:

The datasets which were used in the study include; Temperature and rainfall. The period of study is from 1960-2009, inclusive. The sources and nature of these datasets are presented in the next sub-sections.

a. Rainfall data

The Global Precipitation Climatology Centre (GPCC) has been established in 1989 on request of the World Meteorological Organization (WMO). It is operated by Deutscher Wetterdienst (DWD, National Meteorological Service of Germany) as a German contribution to the World Climate Research Program (WCRP). Mandate of the GPCC is the global analysis of monthly precipitation on earth's land surface based on in situ rain gauge data. Since its start, the centre is the in situ component of the WCRP Global Precipitation Climatology Project (GPCP). The data is provided through their website

Link:http://iridl.ldeo.columbia.edu/SOURCES/.WCRP/.GCOS/.GPCC/.FDP/.version5/.0p5/.prcp/ Adler et al. (2003).

b. Temperature

The temperature data used in the study is Monthly Intrinsic Pressure Level temp (1000hpa).from National Oceanic and Atmospheric Administration NOAA NCEP-NCAR CDAS-1, Kalnay et al. The NCEP/NCAR 40-year reanalysis project , jointly with the University of Colorado The project is involved in the recovery of land surface, ship, aircraft, satellite and other data; quality control and assimilating the data with a system that is kept unchanged over the re-analysis the data is provided through their website.

http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCEP-NCAR/.CDAS-1/.MONTHLY/.Intrinsic/.PressureLevel/.temp/

3.2 The methods used include;

a. EOF analysis

Empirical Orthogonal Functions (EOF) analysis EOF Analysis Empirical Orthogonal Functions (EOF) was utilized to show the temporal and spatial modes of rainfall and temperature variability of the NDJFM season over the region it is been used to perform principal components analysis (PCAs) on time series for both Rainfall and Temperature data. A number of authors including Okoola (1999), Shongwe (2009) and Ongwang et al (2012) have used composite methods in their analyses over the East African region.

b. Trend analysis

Increase or decrease in the number of wet/dry events and seasonal amounts of rainfall can have far reaching implications on many water use activities and the general livelihoods of the society. This part of the study examines the trends in temperature and precipitation over Zambia. Trend is the mean pattern of the time series. In this study such patterns were investigated using both graphical and statistical methods for the interannual variability.

4.0 Results and discussion

This chapter presents the results that were obtained from the methods discussed in the previous section. We begin by presenting the characteristics of rainfall over Zambia.

4.1 Rainfall characteristics

4.1.1 The annual cycle

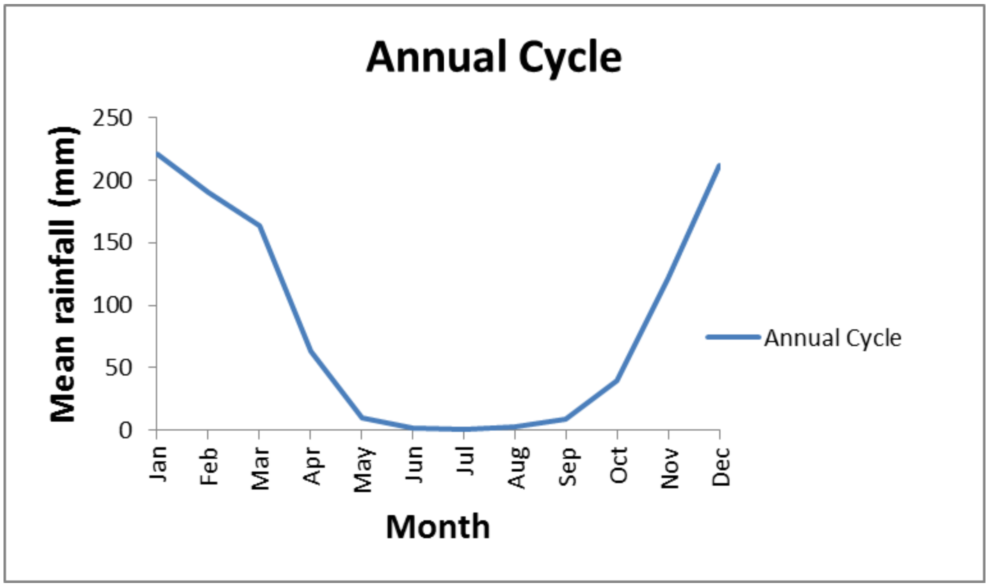


Figure 2: The mean annual cycle of rainfall (1960-2009) over Zambia

The annual cycle of rainfall over Zambia (Fig.2) indicates that the rainfall season lies between November and March (NDJFM) over the region, with the average rainfall in summer around 200mm.June, July and august are the driest months.

4.1.2 Climatology of NDJFM rainfall

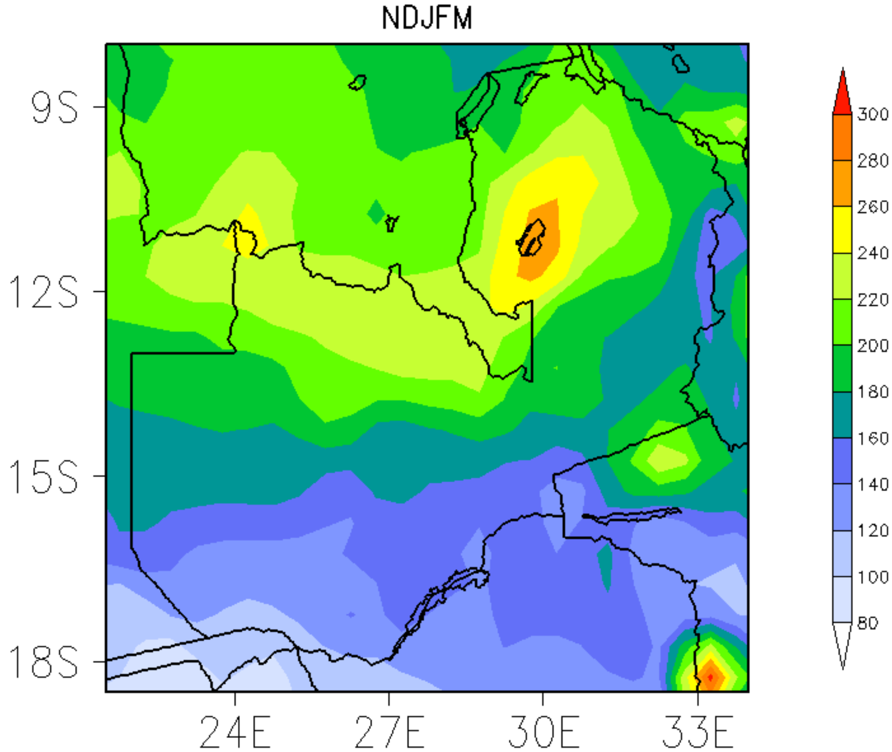


Figure 3: Climatology of November to March (NDJFM) seasonal rainfall over Zambia for the period 1960-2009.

The rainfall climatology of NDJFM (Fig3.) reveals that there is more rainfall received in the northern region compared to the rest of the country. Zambia normally receives the bulk of its annual rainfall from November through out March as the ITCZ moves south. It is worth noting that NDJFM seasons (wet seasons) coincide with the passage of the Inter Tropical Convergence Zone (ITCZ).

4.1.3 Interannual variability of NDJFM rainfall

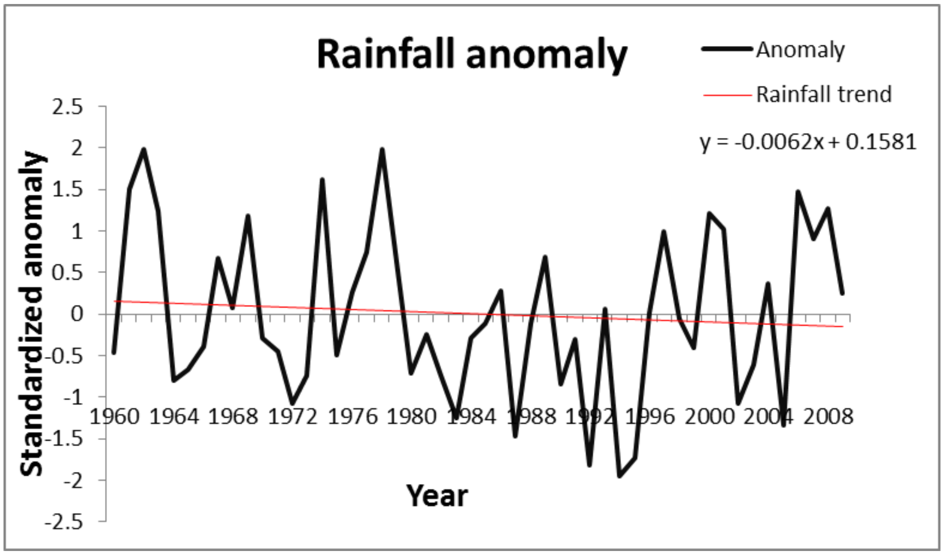


Figure 4: Interannual variability of NDJFM seasonal rainfall over Zambia. The rainfall trend is indicated in the red line.

The interannual variability of NDJFM seasonal rainfall (Fig.4) indicates that the rainfall has been varying with higher frequency of wet events between 1960- 1979. From 1980 to 1996, dry events dominated, thereafter the wet events dominated (1997-2009). In general however, there is a decreasing trend of rainfall in the region (red line), with a rate of decrease of 0.0062 (indicated as -0.0062) mm per year.

This study only gave insights into the trend of rainfall and its variability in the region. More research is required to understand the possible causes of the variability and the observed rainfall trend.

4.2. Results from EOF analysis (of Rainfall)

To understand the dominant modes of rainfall variability and the interannual variability of NDJFM rainfall, EOF analysis was done. The first and second components of EOFs explain 34% and 12% of the total variance respectively. The spatial (EOF 1 & 2) components and their respective temporal (PCs) components are shown in Figs 5-6 . Summing up the percentages accumulated from principal components 1 and 2, the cumulated result is 46% of the total variation in the dataset.

Figure 5, (EOF1) shows a single mode of variability, with positive loadings for all the entire region. Its corresponding PC1 displays rainfall amplitude with years of maximum values as 1961, 1970 and 1974 and those with minimum values as 1984 and 1986 during the study period.

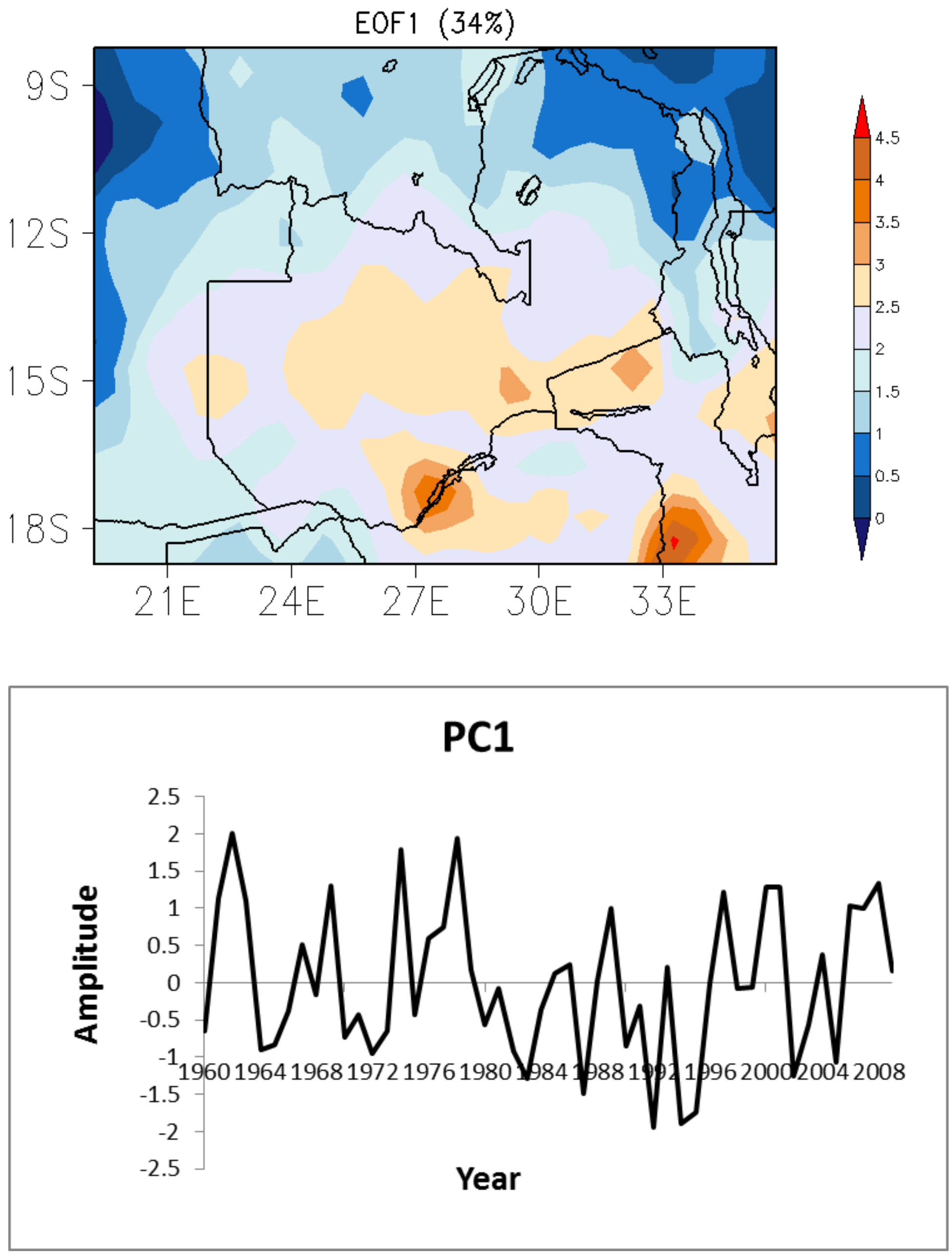


Figure 5: EOF 1 (top), explaining 34% of the variance and the corresponding PC1 (bottom).

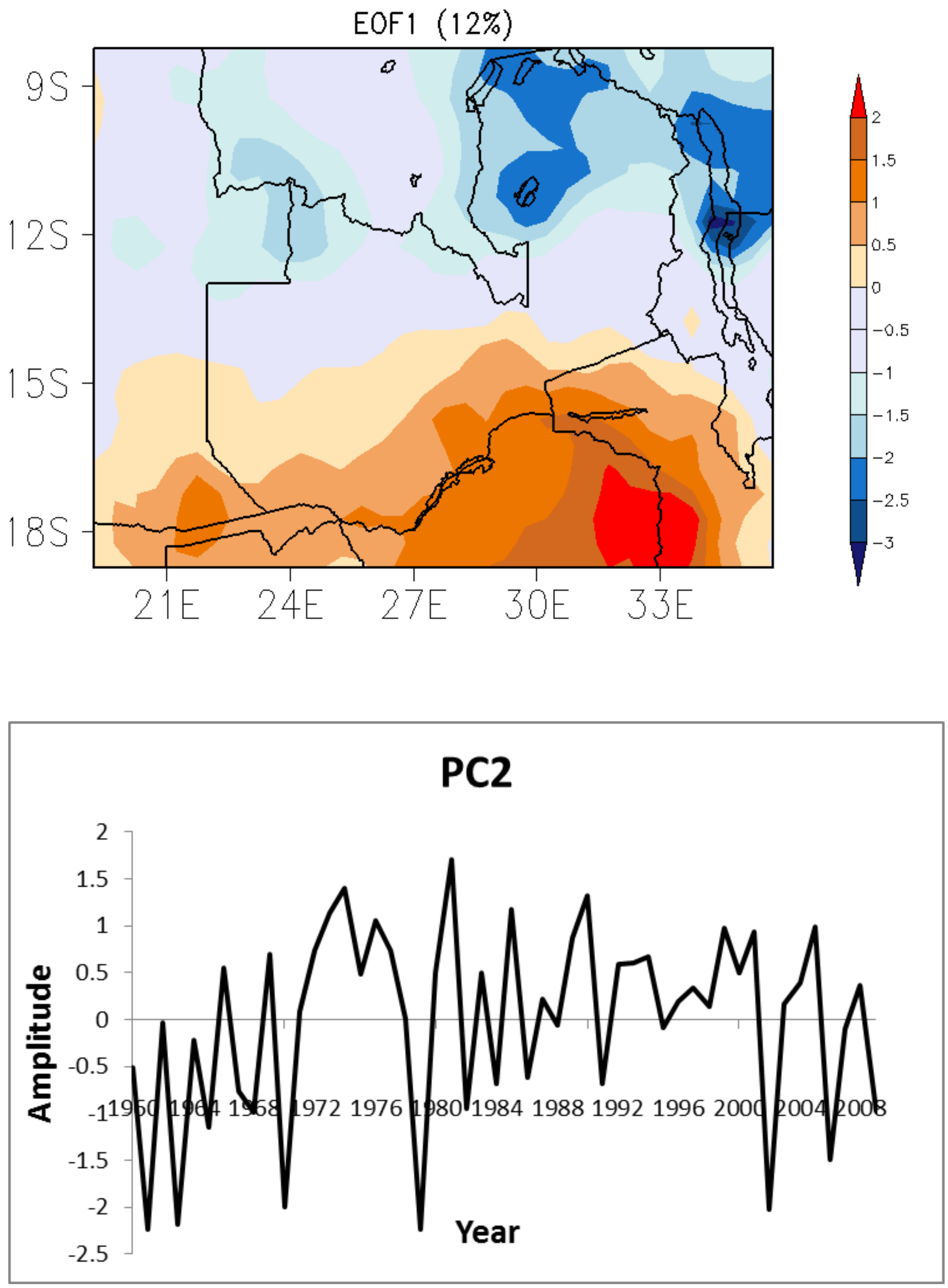


Figure 6: EOF 2 (top), explaining 12% of the variance and the corresponding PC 2(bottom).

Similarly, the second mode, EOF2 and its corresponding principle component (PC2) are shown in Fig. 6. The spatial component shows a two mode pattern of variability, with positive loadings to the southern parts of the region and negative loadings in the northern and northeastern parts.

Its corresponding PC2 displays rainfall amplitude with years of maximum values as 1981 and those with minimum values as, 1961, 1963, 1970, 1979 and 2002 during the study period.

4.3 Temperature characteristics

4.3.1 The annual cycle

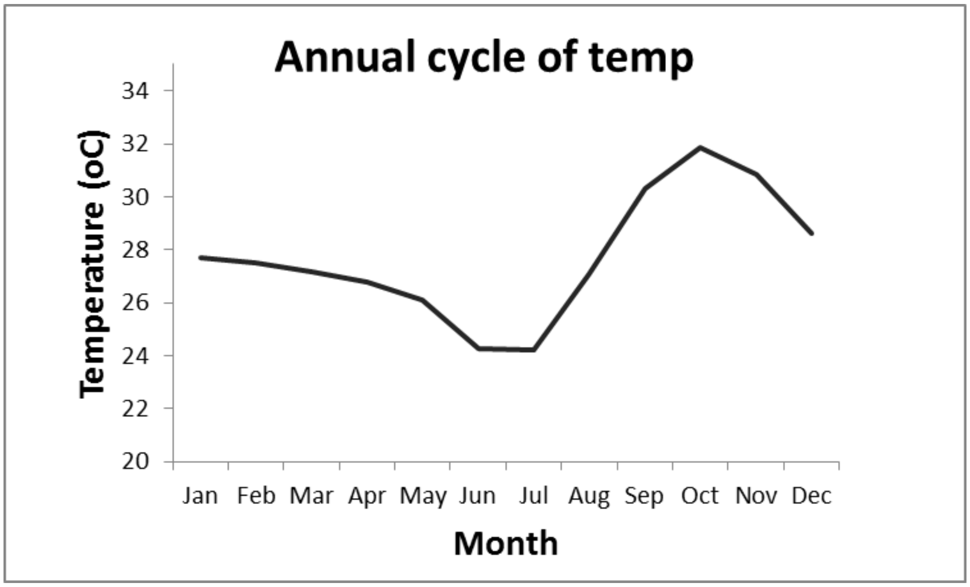


Figure 7: The mean annual cycle of temperature (1960-2009) over Zambia

The annual cycle of temperature over Zambia (Fig.7) indicates that temperatures are higher in the region between Septembers to March, which is in part associated with rainy season (NDJFM) over the region. The low temperatures are observed during June and July.

4.3.2 Climatology of NDJFM temperature

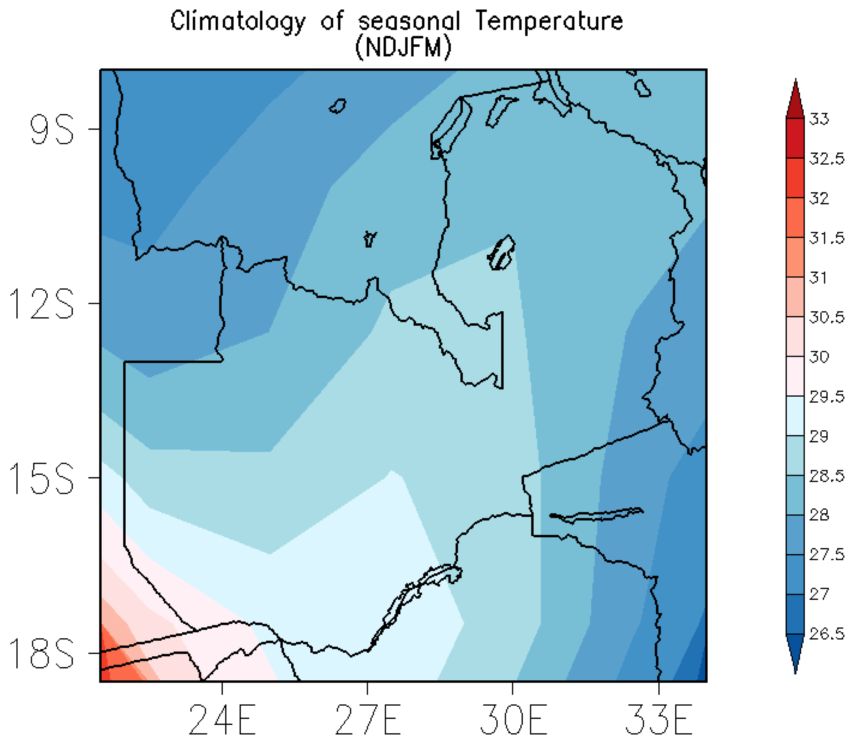


Figure 8: Climatology of November to March (NDJFM) seasonal temperature over Zambia for the period 1960-2009.

The temperature climatology of NDJFM (Fig.8) reveals that the temperature is higher in the southern part than the northern region, where the mean seasonal rainfall is low (shown in Fig. 3). The I.T.C.Z moves northwards towards the end of summer and remains for a longer period of time in the northern part of Zambia than in the southern parts of the country which leaves the southern part with less moist resulting in high temperatures. The northern part of the country receives more rainfall because it is nearer to the Equator. When the North-West rain-bearing winds and the North-East monsoons blow from the Equatorial region into the northern part of the country, they are more moist and bring more rain to the northern part of the country. As the wind progresses southwards, they become drier losing moisture as they move. Hence, the southern part of the country receives less rainfall than the northern parts of Zambia.

4.3.3 Interannual variability of NDJFM temperature

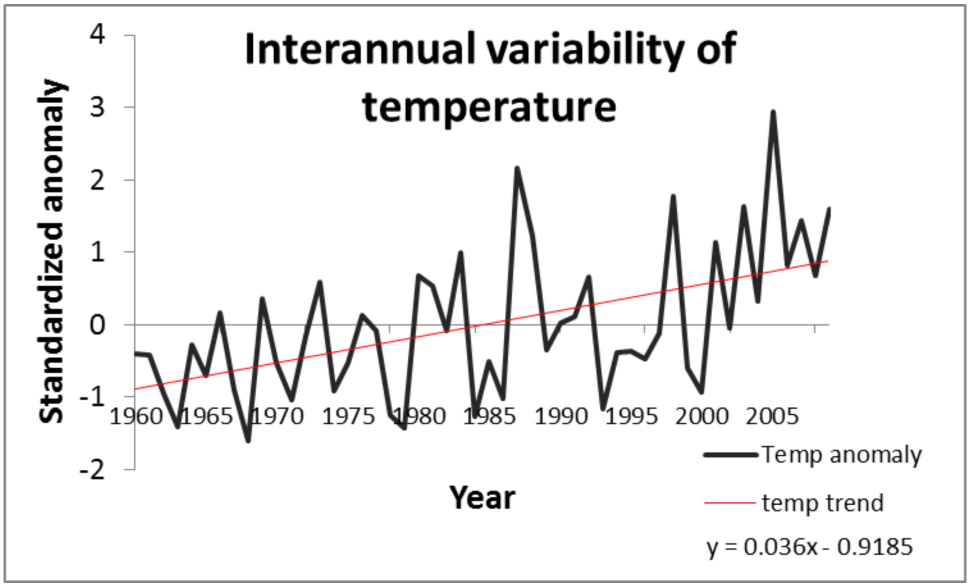


Figure 9: Interannual variability of NDJFM seasonal temperature over Zambia. The temperature trend is indicated in red ink.

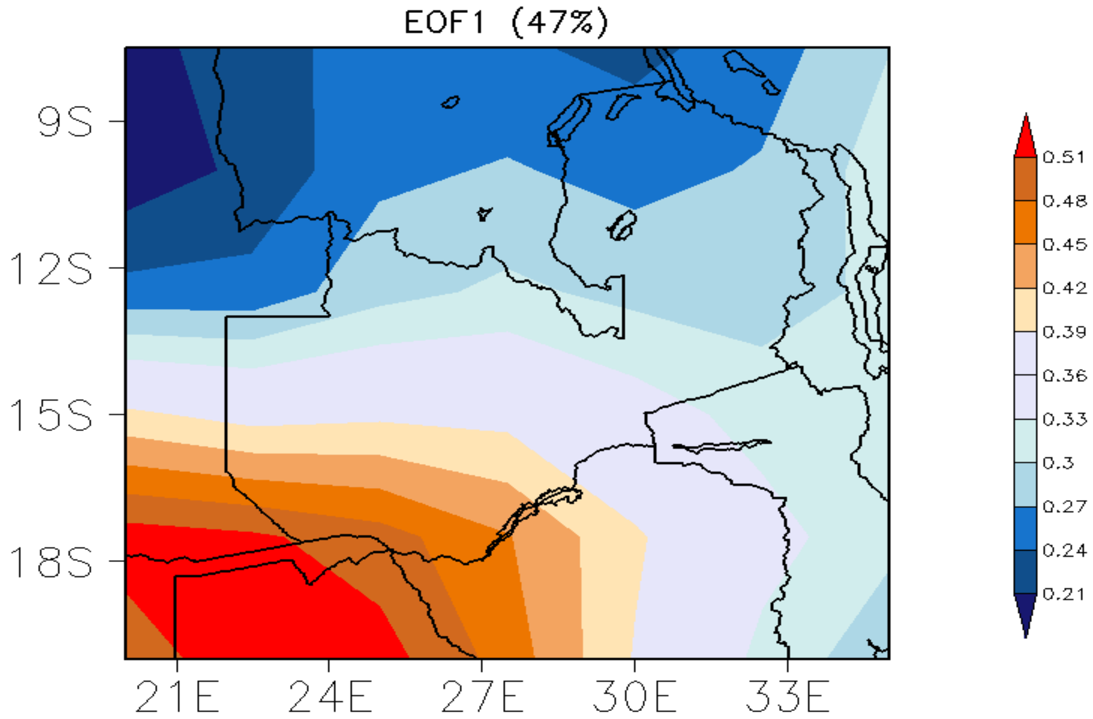
The interannual variability of NDJFM seasonal temperature (Fig.9) indicates that temperature has been varying with higher frequency of cold events between 1960- 1985. After this period, warm events (above normal temperature) dominated. In general however, there is an increasing trend of temperature in the region (red line), with a rate of increase of 0.036oC per year.

This study only gave insights into the trend of temperature and its variability in the region. More research is required to understand the possible causes of the variability and the observed increase in temperature trend

4.4. EOF analysis (of temperature)

To understand the dominant modes of temperature variability and the interannual variability of NDJFM temperature, EOF analysis was done. The first and second components of EOFs explain 47% and 33% of the total variance respectively. The spatial (EOF 1 & 2) components and their respective temporal (PCs) components are shown in Figs 10-11. Summing up the percentages accumulated from principal components 1 and 2, the cumulated result is 80% of the total variation in the dataset.

Fig 10, (EOF1) shows a single mode of variability, with positive loadings for all the entire region. Its corresponding PC1 displays temperature amplitude with years of maximum values as 1983, 1987, 2003,2005,2007 and 2009 and those with minimum values as, 1968,1978,1993,and 1999.



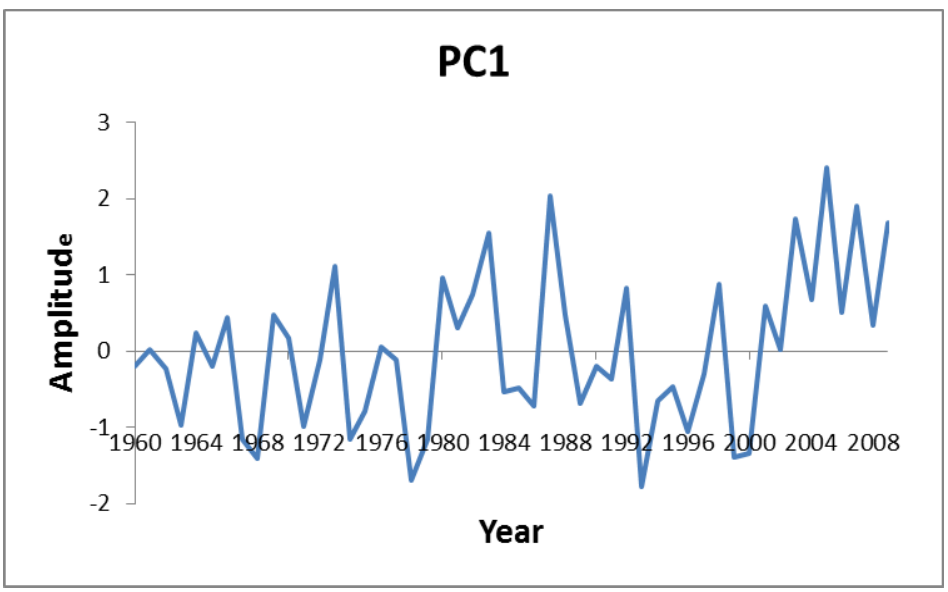
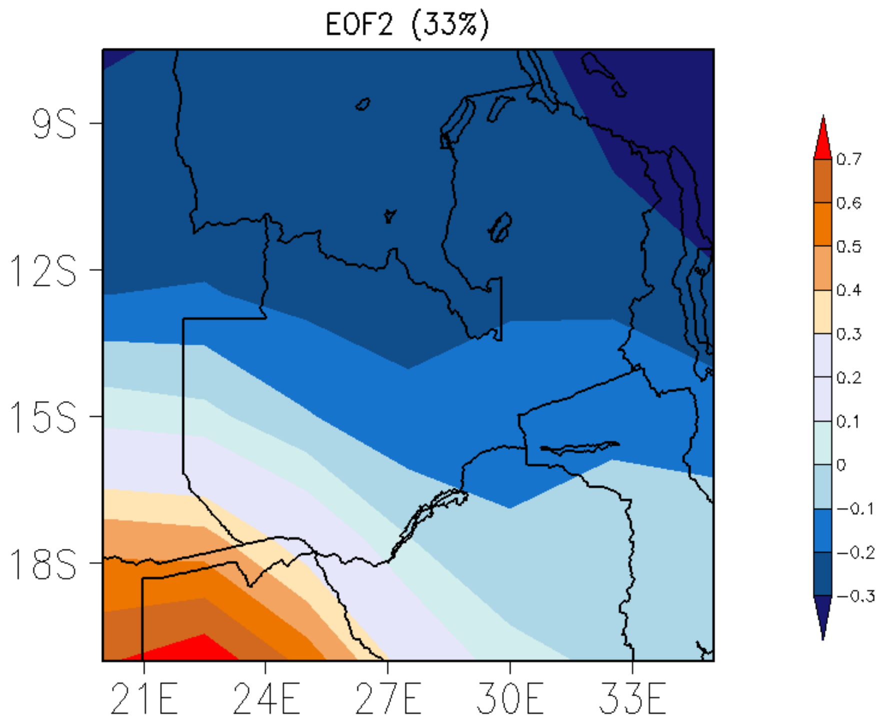


Figure 10: EOF 1 (top), explaining 47% of the total variance and the corresponding PC1 (bottom).



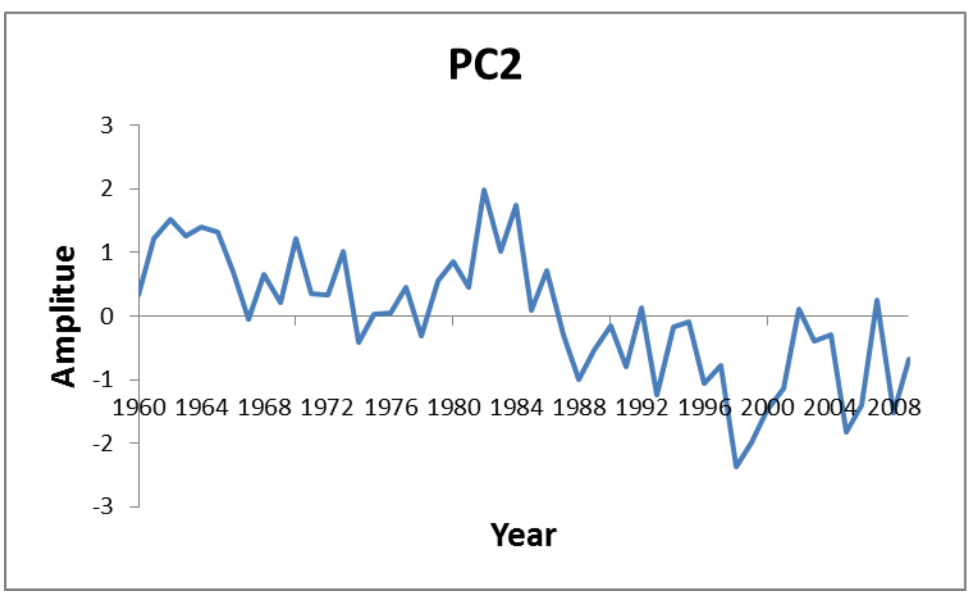


Figure11**:** EOF 2 (top), explaining 33% of the total variance and the corresponding PC2 (bottom).

Similarly, the second mode, EOF2 and the corresponding principle component (PC2) are shown in Fig.11. The spatial component shows a triple mode pattern of variability, with positive loadings to the southwestern parts of the region and negative loadings in the northern, central and southern parts of the region Its corresponding PC displays temperature amplitude, with years of maximum values as 1962, 1964, 1982 and 1984 and those with minimum values as 1998,1999 and 2005.

5.0 Summary and Conclusion

This chapter provides the summary of the results of this study and the major conclusions drawn. The objective of this study was to understand the spatial and temporal characteristics of Nov-Mar rainfall over Zambia, investigating the spatial and temporal characteristics of seasonal (NDJFM) temperature, and the rainfall and temperature trends over Zambia.

Results show that the annual cycle of rainfall over Zambia depict one rainy season which lies between November and March (NDJFM) over the region, with the average rainfall in summer around 200mm. whereas the annual cycle of temperature over Zambia indicates that temperatures are higher in the region between Septembers to March, which is in part associated with rainy season (NDJFM) over the region. The low temperatures are observed during June and July. The rainfall climatology of NDJFM reveals that there is more rainfall received in the northern region compared to the rest of the country which is opposite with temperature climatology of NDJFM. In general however, there is a decreasing trend of rainfall in the region (red line), with a rate of decrease of 0.0062 (indicated as -0.0062) mm per year. The interannual variability of NDJFM seasonal temperature indicates that temperature has been varying with higher frequency of cold events between 1960- 1985. After this period, warm events (above normal temperature) dominated. In general however, there is an increasing trend of temperature in the region (red line), with a rate of increase of 0.036^{o}C per year.

The dominant mode of variability for both temperatures and rainfall exhibits single modes of variability with positive loadings for the entire region.

The statistical analysis approaches used in this study provided insights into the NDJFM rainfall and temperature trends and variability. Further work based on numerical simulations is required to fully understand the physical mechanisms responsible for the observed variability and trend.

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