El Niño Southern Oscillation (ENSO) and its Effect on Rwanda Climate.

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Abstract:

The sea surface temperature (SST) in the tropical pacific region known as Niño1, 2, 3, 3.4 and 4 regions are always analysed to identify the El Niño-Southern Oscillation (ENSO) episode. As SST in that region exceed the normal SST (warm period) at that time the El Niño (EN) event is on, and contrary when it is lower than the normal SST it is the La Niña (LN) event. The two events have a global atmospheric pressure oscillation named ENSO. In this study we look on overview of this phenomenon during a period of 34 years (1983-2017) and the target is to analyse generally this phenomenon mainly some of the strong events, to generalise the health effect related, and in particular to identify its effect on Rwanda climatology by analysing the annual mean trends of rainfall, maximum and minimum temperature. The objectives of this research was reached and expanded. The annual mean rainfall, maximum and minimum temperature for the non ENSO years are 2.83mm, 25.66ºC and 14.33ºC respectively while every station's data is mentioned in this study. We focus on the strong ENSO event and even the recent EN (2019-2020) for its general situation, the study has shown that EN event cause the annual mean maximum and minimum temperature across the Rwanda to increase except EN of 1997-1998 and LN cause the decrease of both annual mean maximum and minimum temperature except LN of 1998-1999. For annual mean rainfall, this study has shown that ENSO episode itself does not explain the variability of rainfall over Rwanda but there are other rainfall drivers mentioned in this study to be considered for a full reason of the rainfall variability including ITCZ, topography, subtropical anticyclones etc.

Keywords: ENSO, Temperature, Rainfall, Pacific Ocean, Rwanda.

1. Introduction

The name El Niño (EN) meaning "the little boy" or "the Christ child" (Reid, 2000) comes due to its known appearance event around the Christmas season (NOAA, 2006) and the EN episode began long years ago where it was predicted by climate scientist as the exceptionally warm sea surface temperatures (SST) in the tropical Pacific as shown on figure 1, and this has different major changes in the atmosphere (Trenberth, 2013; Hirons and Klingaman, 2016; Anyamba et al., 2018) known as a global atmospheric pressure oscillation and the scientist name this phenomenon as El Niño Southern Oscillation (ENSO) (Trenberth, 2013; NOAA, 2006; WMO, 2014) and this is the best known example of quasi-periodic natural climate variability on the interannual time scale (Kovats, 2014; Piton and Delcroix, 2018; Plisnier et al., 2000) and also an important driver of inter-annual variations in climate (Kohyama et al., 2018) and ecosystem productivity mainly in tropical regions (Plisnier et al., 2000) and other region. ENSO is associated with changes in the atmospheric circulation (Dijkstra, 2006) with strong impacts on the meteorological conditions on a global level as well as tropospheric temperature and rainfall (Nexus, 2016; Indeje et al., 2000), and linked to the Walker circulation changes, regional winds and vertical velocities over East Africa (Ummenhofer et al., 2018), CO_2 concentration, pressure (Ogalo and Janowiak, 1988). Since 1932 Walker and Bliss come up with the term Southern Oscillation in order to identify a global-scale phenomenon including change in features, the atmospheric pressure field difference between the eastern and western tropical Pacific etc (Trickl , 1982; Wang et al., 2017). ENSO is characterized by the changes in the sea temperature in central and eastern tropical Pacific Ocean and the patterns of sea level pressure, lower and upper level winds, and tropical rainfall across the Pacific basin (NOAA, 2018; Zhaohua et al., 2005), and normally the mean rainfall or temperature across East Africa reduces or increases as topography elevation is changed (Ogwang et al., 2014) and Temperatures across different region was increased by 1.5 to 2°C on average over the past 50 years where the highest increases are found in central regions, especially in South Sudan where 3ºC was exceeded during March to August (Daron, 2014). Simply the warm event is EN where the coastal waters near Peru were abnormally warm (Reid, 2000) and contrary cold event is La Niña (LN) (Trickl , 1982; WHO, 1999; Hirons and Klingaman, 2016) named also "Pacific cold episode." (NOAA, 2006). The major net effect of both strong LN and strong EN events lead to enhanced entry water vapor and stratospheric moistening in boreal spring and early summer (Garfinkel, 2018; WMO, 2014). ENSO cycle ranging from about two to seven years and the sea temperature changing is from ± 1ºC to ± 3ºC compared to the normal condition across

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central and eastern tropical Pacific Ocean (NOAA, 2018; Kovats, 2014; UNESCAP 2016; Anyamba et al., 2018). ENSO is a major mechanism for maintaining long term global climate stability by transporting heat from the Tropics to the higher latitudes (NOAA, 2006; Ying and Ngar-cheung, 2011). In fact the major index used for determining the global impact of the SO on sea level pressure (SLP), air temperature, and rainfall is Southern Oscillation Index (SOI) (Trickl , 1982). NOAA's Climate Prediction Center determine the average monthly sea surface temperature for a particular region known as Niño1, 2, 3, 3.4 and 4 regions (Chunzai et al., 2017) located between Tahiti and Darwin, (Trenberth, 2013) as shown on figure 1 and the information retrieved show if the ENSO is in (NOAA, 2018) NOAA has 70 stationary network in the equatorial Pacific, called the Tropical Atmosphere/Ocean (TAO) array, which provides data about upper ocean and sea surface conditions which was used in this study. Other important data come generally from satellites, radiosondes, and the high-density U.S. surface data network (NOAA, 2006).

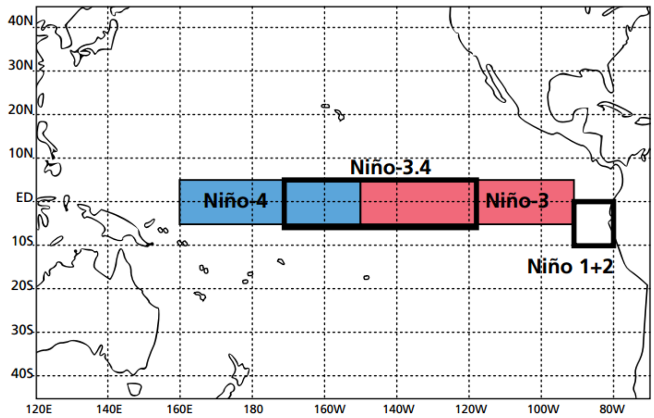

Figure 1: Different region considered to identify current situation of ENSO.

As Rwanda is located in the equatorial belt, ENSO episode has several impacts on country climate including rainfall and temperature variability and the main outcomes of these changes include floods, landslides and droughts (ICPAC, 2009; Muhire, 2014; Ndayisenga, 2020; Nicholson, 2017). Globally ENSO is linked to the increases of natural disasters impact (Kovats, 2014). During EN episode, the climate of Rwanda and generally that of East Africa has a substantially increased probability of being unusually wet during the secondary and shorter rainy season of OND, whereas the region's primary and longer rainy season, MAM, is largely unaffected as summarized on figures 4a and 4b. The natural disasters in Rwanda is associated with food, energy and water shortages, loss of life and property, migration of peoples from high risk zone(escaping natural disasters direct impact) (Hirons and Klingaman, 2016) and many other socio-economic disruptions (Indeje et al., 2000) and diseases (Ndayisenga 2020).

2. ENSO Phases

As NOAA (2018) mentioned, there are three phases as shown on figure 2, namely neutral, El Niño and La Niña (WMO, 2014) also known as Oceanic components (Mitra et al., 2014) these phases indicates strong trade winds blowing from the east along the equator which pushes warm water into the western Pacific Ocean, warm waters from tropical latitudes of the central and eastern Pacific Ocean cause weakening of the low level easterly winds and the result is to shift tropical rains (Ndayisenga, 2020) that usually fall over Indonesia to eastward, cold waters from the central and eastern tropical Pacific strengthen the low-level easterly winds over the central tropical Pacific with the result of heavy rainfall over Indonesia and Malaysia respectively. The thermocline layer shown on figure 2 separate the warmer water surface from the colder deep water.

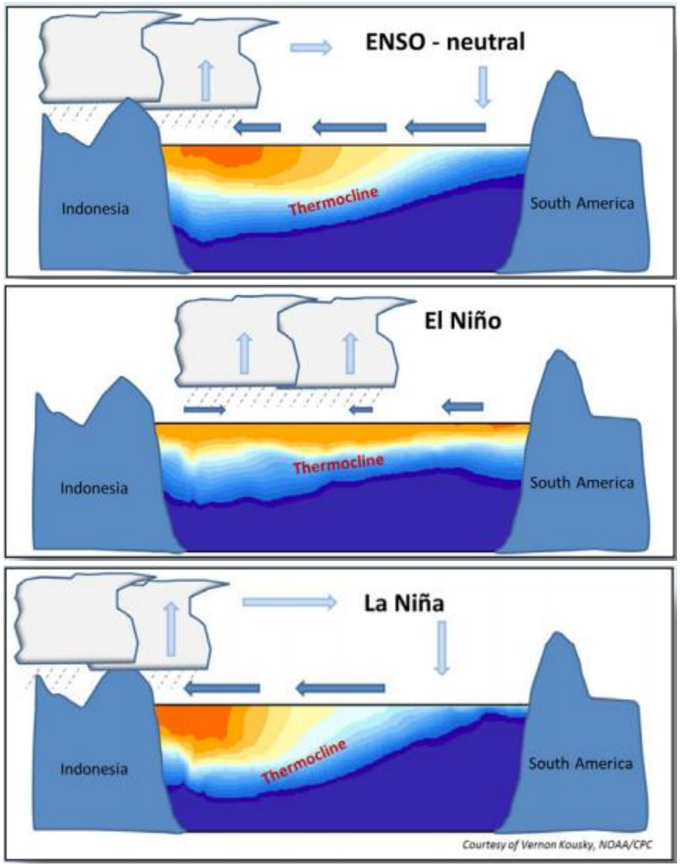

Figure 2: ENSO Phases (NOAA, 2018)

There are several physical processes take place to the ocean controlling ENSO events. About 50m death of top layer of Ocean are well mixed and also its temperature changes by atmospheric air interaction but this layer mix with the deeper Ocean's water by advection processes. Here the net heat flux from atmosphere to the top layer of Ocean is Q_{oa} while for the bottom Ocean's layer is Q_b. By approximation we consider the temperature for each of the two mentioned layers to be homogeneous; here Dijkstra (2006) shows the results of integration of heat balance equation over those layers by equation (1) below

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$$\frac{\partial T}{\partial t} = -\left(u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y}\right) + F_T^H(T) + \frac{Q_{0a} - Q_b}{\rho C_p H_m} \quad (1)$$

Where C_p is the heat capacity of water, H_m is the mean depth of the mixed layers, ρ is the mean density, (u, v) are horizontal mixed layer velocities and F_T^H represent horizontal mixing of heat through lateral turbulent exchange process. This equation shows that the mixed layer temperature can change with the process of advection as indicated by two first term of our right hand side equation and also vertical and horizontal exchange processes. From (1) Dijkstra (2006) reduce the net Ocean atmosphere heat flux (Q_{0a}) with temperature change between upper Ocean and lower atmosphere as below

$$\frac{Q_{0a}}{\rho C_p H_m} = \epsilon T \,(T - T_a) \quad (2)$$

With ϵT the proportionality constant. But at the lower boundary of the mixed layer, the approximation of the heat flux at that layer becomes

$$\frac{Q_b}{\rho C_p H_m} = \omega \,\frac{T - T_s}{H_u} \quad (3)$$

With ω a typical vertical velocity at the bottom of the mixed layer while H_u is a vertical length scale where the temperature gradient between the mixed layer and that of subsurface (T_s) as shown on figure 3 is very well approximated.

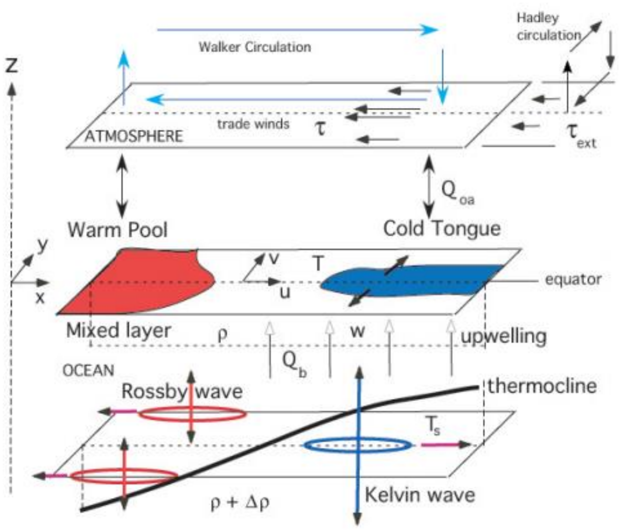

Figure 3: Equatorial Oceanic and atmospheric processes (Dijkstra, 2006)

3. Data collection site

The meteorological parameters considered in this study were temperature and rainfall and the data was collected from several Rwanda weather stations. Figure 4 represents data collection weather station. All four provinces were represented by at least 2 weather stations and similarly in Kigali City. For ENSO different data sets, including IRI and NOAA was used.

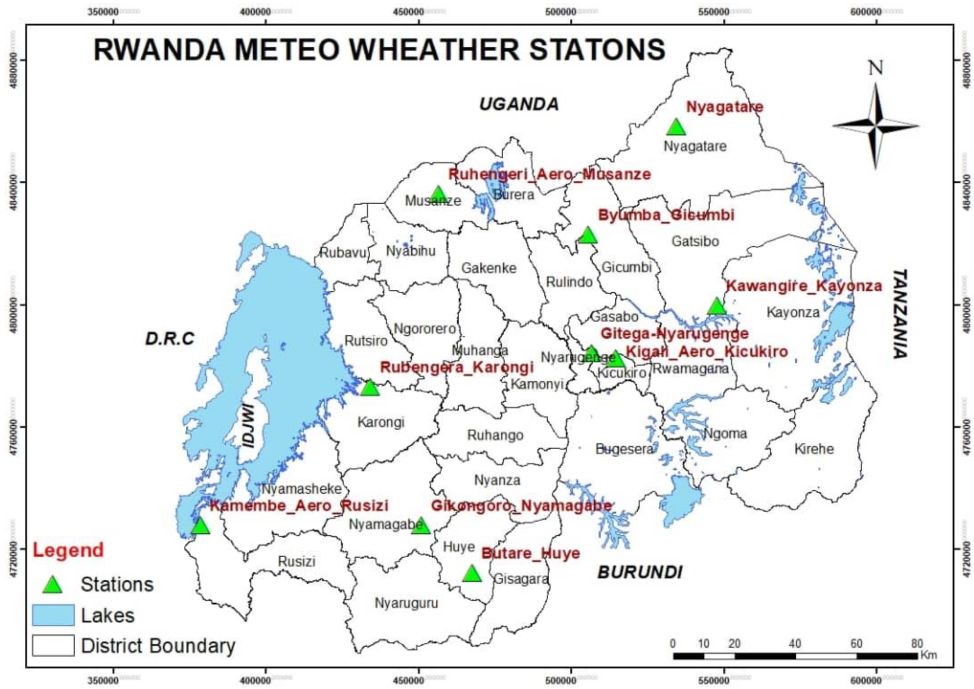

Figure 4: Data collection site

4. Methodology

In this study we use IRI data library especially NOAA NCEP CPC CAMS dataset to retrieve global data for analysis of the ENSO effect over Africa and generally to the whole globe. The weather data collected from different weather station in Rwanda was analyzed using R programming in order to correlate the full weather information to the ENSO event to know its effect to Rwanda. The resent ENSO data are obtained

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from NOAA's Climate Data Center. There is some basic knowledge needed to identify the current ENSO events. The LN events occur when SST anomalies in the Niño-3.4 region (5S–5N, 170W–120W) as shown on figure1are negative and less than 0.5ºK, and EN events occur when SST anomalies in Niño-3.4 region are larger than 0.5ºK. Both LN and EN events are categorized into different four groups which are: central Pacific (CP) EN which is characterized by positive SST anomalies in the Niño-4 region (5S–5N, 160E–210E), and eastern Pacific (EP) EN which is characterized by positive SST anomalies in the Niño-3 region (5S–5N, 210E–270E), and also CP LN and EP LN characterized by negative SST anomalies in both Niño-3.4 region and Niño-4 region shown on figure 1. But EP LN events occur when the Niño-3 anomaly is 0.1ºK less than the Niño-4 anomaly, and EP EN events occur when the Niño-3 anomaly is 0.1ºK larger than the corresponding Niño-4 anomaly (Garfinkel, 2018).

5. Results and discussions

5.1. Temperature anomaly during EN event 1983

We prefer to consider EN 1983 because it was the strongest among other EN events.

Particularly for temperature anomaly over Africa during this EN event: JJA 1983 as shown on figure 5, in South part of Africa and small North West Africa part the temperature anomaly is +2ºC and a big part of North East part and smallest part of South Africa approaching the Ocean is -2ºC, this is logically fit to the theory which state that in case of EN event that part is warm and dry and even 2019 EN episode global map 6a mention. The temperature anomaly in Africa is not dramatic as figure 5 summarize it, even if in southern Africa region the anomaly is high around +2ºC due to desert effect, simply un-vegetated lands absorb more incident insolation than vegetated lands and re-emit more infrared which increase temperature and also dust in atmosphere due to the wind blow play a big role to increase temperature in that region, while in North West part there is anomaly around -2ºC.

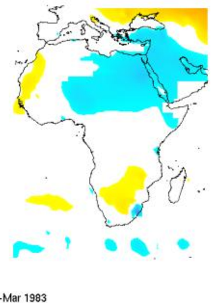

Figure 5: 3 months of EN event: Jun-Aug 1983.

5.2. EN event 2019

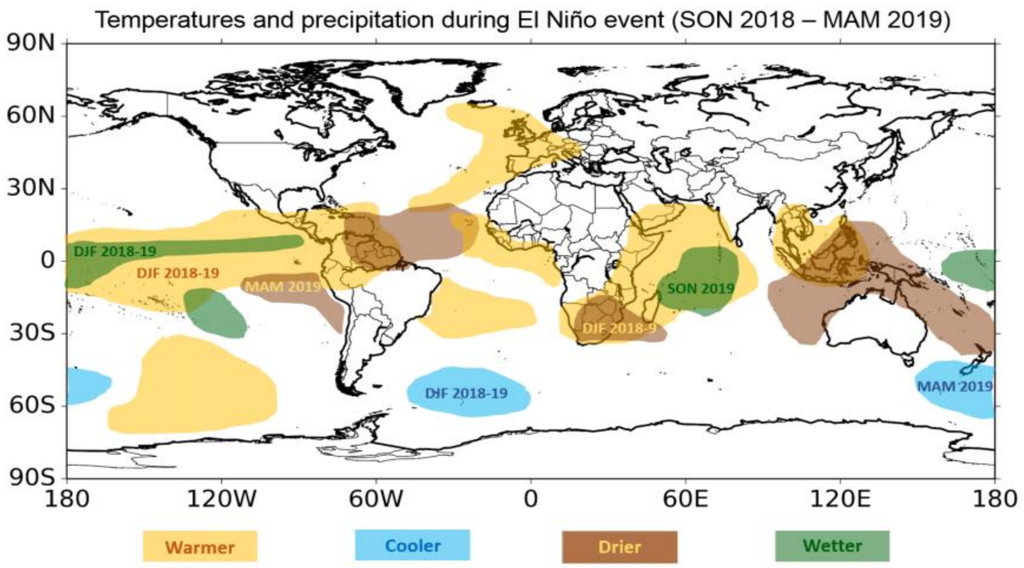

Figure 6a: Effect of EN on climate (Klingaman and Keat, 2018)

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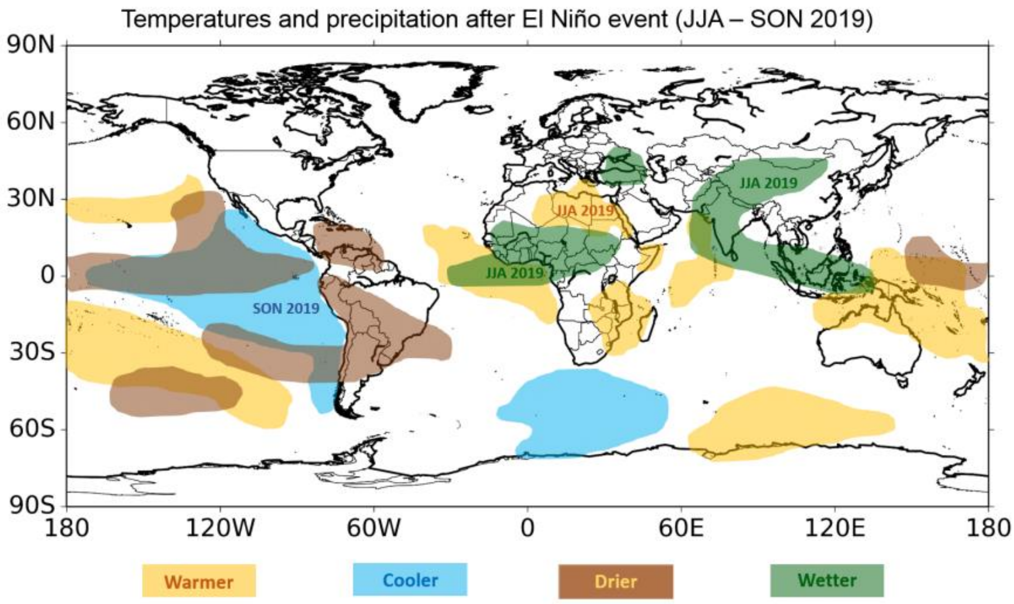

Figure 6b: Climatic condition after EN (Klingaman and Keat, 2018)

The figures 6a and 6b summarize the major impacts on seasonal precipitation and near-surface temperature over land areas for the recent EN events. For figure 6a the map was obtained using data for September through March during the peak of an El Niño as provided by Klingaman and Keat (2018). Where extremes are likely only in one season, that season is labelled inside the shaded region. Regions without a label have likely changes in extremes throughout the period.

While for 6b the map was obtained using data for June through November after the peak of an El, the extremes are likely only in one season, that season is labelled inside the shaded region. Regions without a label have likely changes in extremes throughout the period.

Recently from early June 2018 through May 2019, near-to-above average SSTs were present across most of the Pacific Ocean as shown on figure 7 and 8.

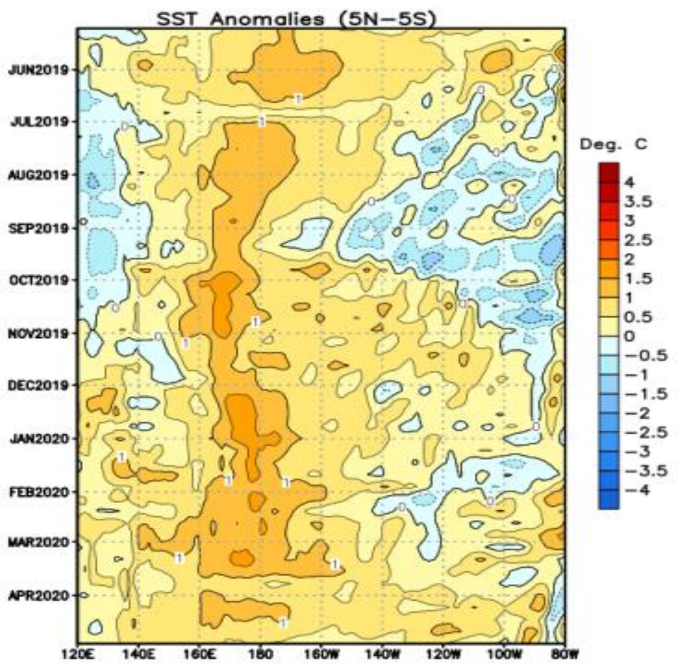

Figure 7: SST of equatorial Pacific Ocean.

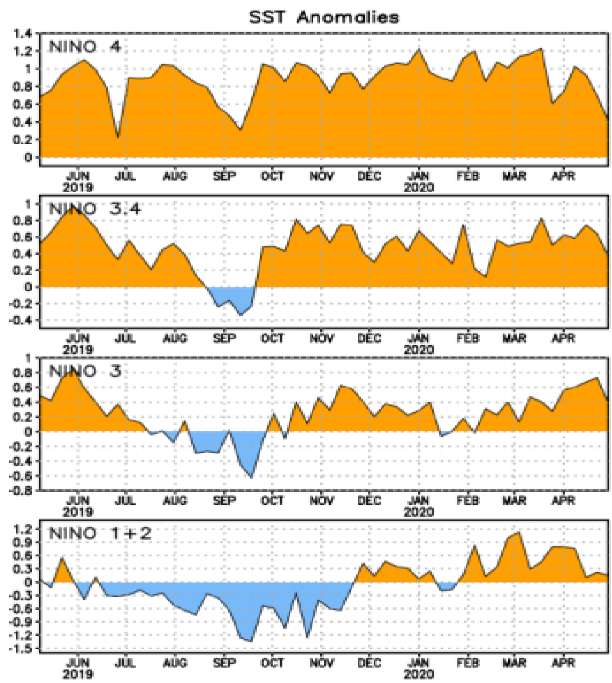

Figure 8: SST in different Niño region.

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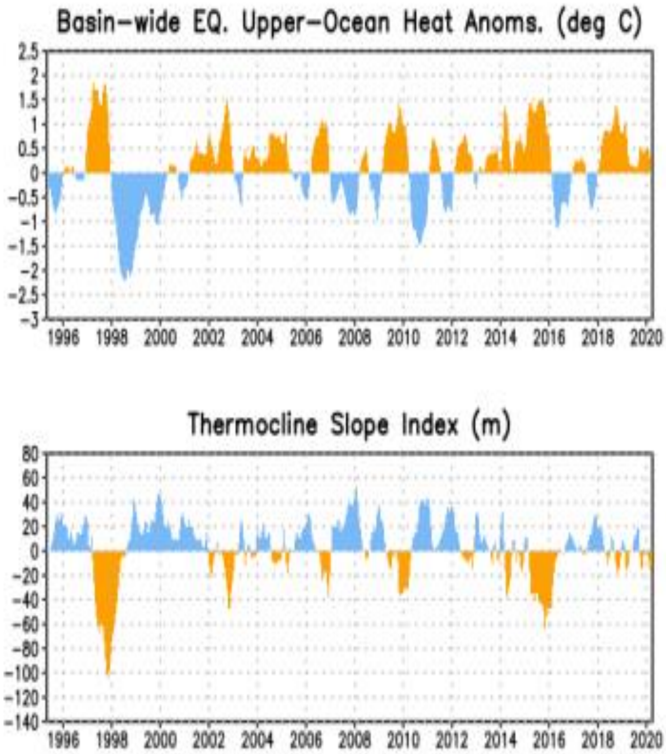

Figure 9: Upper Ocean conditions in the equatorial pacific (1996- April 2020)

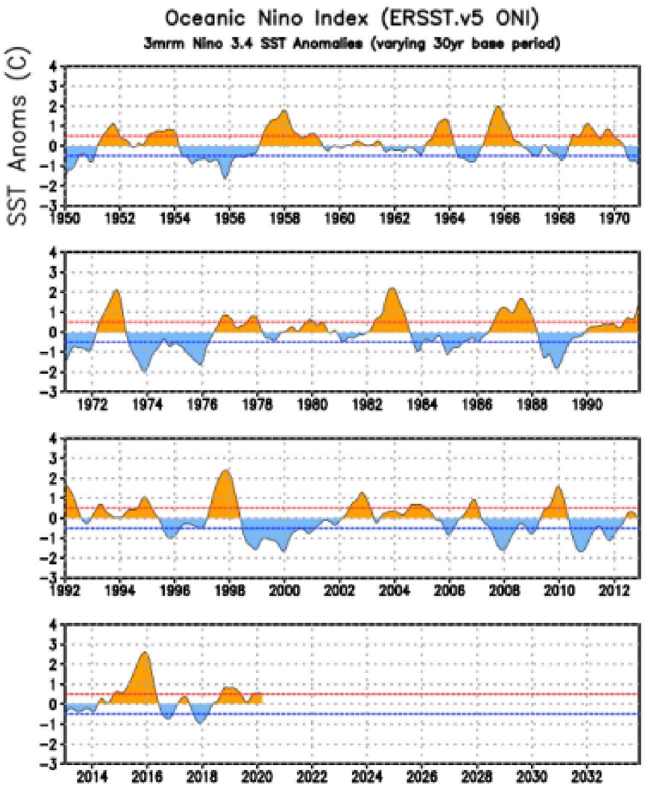

Figure 10: ONI from 1950 to 2020

Figure 7 shows that the SST anomaly of equatorial Pacific Ocean increase up to 2ºC, from July up to September 2019 below average SST expanded westward into the East-Central Pacific while in mid-September 2019 above average SST expanded from the date line (DL) into the Eastern Pacific Ocean. As figure 9 shows, the basin wide equatorial upper ocean at altitude of 0-300 m heat content is greatest prior to and during the early stages of a Pacific warm period or EN event, and least prior to and during the early stages of a cold period also known as LN event, the recent ONI value (February to April 2020) is +0.5ºC and also it shows the slope of the oceanic thermocline is least during EN event and greatest LN event. Thus the values of the upper-ocean heat anomalies (near average) and thermocline slope index (near average) reflect ENSO-neutral where the circulation processes is shown in figure 1. Normally the monthly thermocline slope index represents the difference in anomalous depth of the 20ºC isotherm between the Western Pacific from 160ºE to 150ºW and the Eastern Pacific from 90º to 140º.

Here figure 11 show a positive OLR anomalies means suppressed convection and precipitation, were evident over parts of the Philippines, Indonesia, and around the date line. Low level (850 hPa) the wind anomalies were observed to be Easterly over the East Central equatorial Pacific Ocean. And also the wind anomalies for the upper level (200 hPa) were Westerly over the Central and Eastern tropical Pacific.

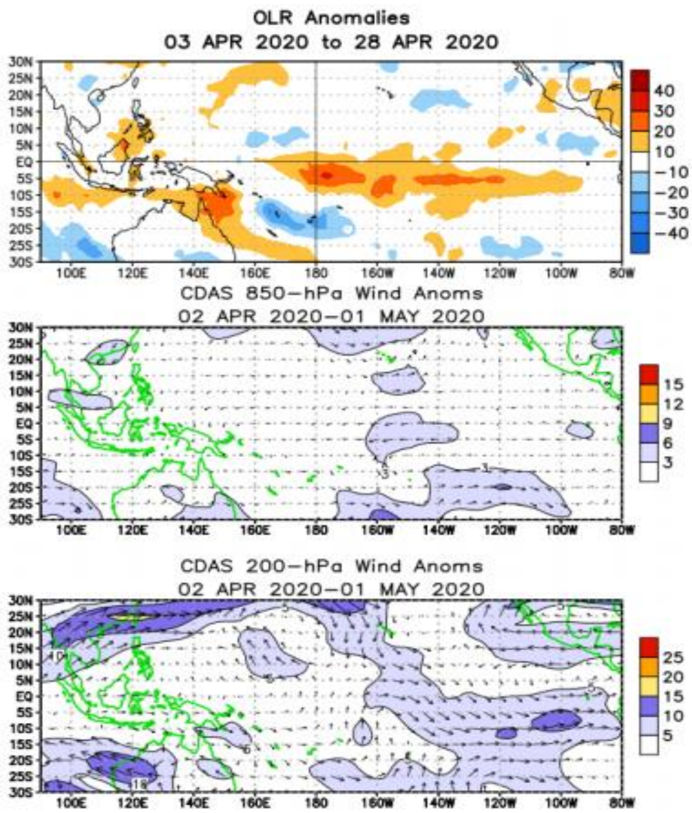

Figure 11: Tropical outgoing longwave radiation (OLR) and wind anomalies during the Last 30 days of EN

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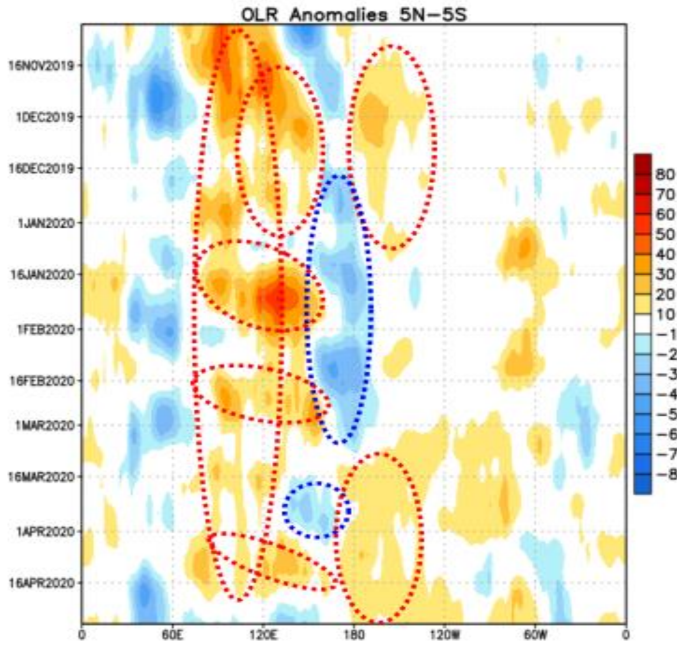

Figure 12: OLR anomalies from Nov 2019 to Apr 2020

While figure 12 indicate that from mid-November through December 2019, positive OLR anomalies were evident near and just East of the DL and from mid-December through February 2019, negative OLR anomalies were observed near and west of the DL, and from July 2019 through mid-April 2020 positive OLR anomalies persisted over Indonesia. Since mid-March, positive OLR anomalies were observed at the DL.

5.3. Creating the SOI

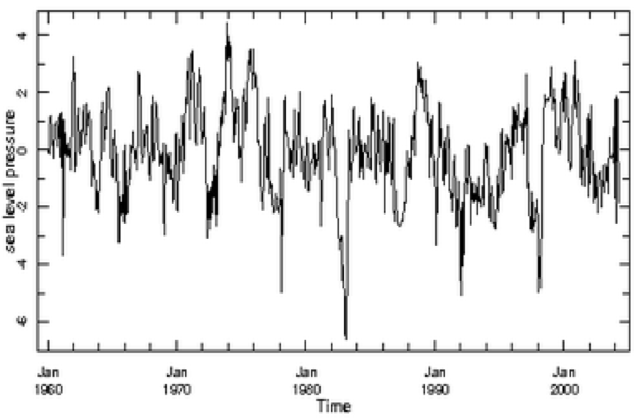

Figure 13: Standardized indices Tahiti-Darwin full anomaly

This is a graph of the Southern Oscillation Index (SOI) means standardized sea level pressure anomalies at Tahiti minus standardized anomalies at Darwin from January 1960 to April 2004 a period of 44 years. Negative values represent higher-than-average surface pressures at Darwin and lower-than-average surface pressures at Tahiti, which in turn, often correspond to El Niño conditions. The exceptionally strong El Niño event of 1982 / 1983 is predominent in this figure 13.

6. ENSO and its health impact

Apart from natural disasters (Kovats, 2014; Soon, 2008) including droughts, floods, landslides (NOAA, 2016; SEI, 2009; MIDIMAR, 2015; Ndayisenga, 2020) as WHO (1999) shows that the East Africa countries are vulnerable for drought (even view their figure 2.3) and tropical cyclones which cause famine caused by seasonal change which affect crops production (Ngabitsinze et al., 2011; Zhenhua et al., 2018; Anyamba et al., 2018), death etc, there is a clear scientific evidence show that ENSO is associated with strong risk of certain vector-borne diseases in specific geographical areas where weather patterns are linked with the ENSO cycle and disease control is limited (Kovats, 2014). Mostly such diseases include malaria in different region of Rwanda (Ndayisenga, 2020), but there is other Global part where there are epidemics of other mosquito-borne and rodent-borne diseases that can be caused by extreme weather conditions including dengue fever more intense in Asia, rift Valley fever affecting mainly cattles and human which was intense in Kenya and Somalia between October 1997 to January 1998, yellow fever**,** ross river virus disease in Australia**,** murray Valley Encephalitis in Australia, rodent-borne diseases (including hantavirus pulmonary syndrome in the United States) (WHO, 1999), water-borne diseases (including cholera and diarrheal diseases) (Kovats, 2014; WHO, 1999) biotoxins: fish and shellfish poisoning (WHO, 1999). And the results of the above deseases are the deaths and poverty (UNESCAP, 2016). There is a need of scientific research to determine the nature of the ecological mechanisms of relationships between ENSO and those mentioned diseases. EN have several negative impacts in agriculture sector including a decrease in crop production, forest fires burning and even agriculture lands in the forest fire prone zones, loss in subsistence agriculture etc. and even in water resources EN event dry the stream, rivers and other water reservoir and also decrease ground water level. EN damage infrastructures due to floods, landslides and cyclones, human settlements and irrigation infrastructures (Watkiss, 2018; MINIRENA, 2011). Even if the negative impacts are more than the positive, we do not neglect these positive impacts of EN including optimal crop production unless it is not flooded, optimal ground water level , to enhance steam or river flow, and Surplus water in water harvesting structures and reservoir (UNESCAP, 2016). ENSO event reduces also CO_2 uptake of oil palm plantation (Stiegler et al., 2019) and generally crops production (Fer et al., 2017). Large numbers of inland fisheries subregions becomes vulnerable by EN as (Stiegler et al., 2019) observe a negative production anomaly. However, the ENSO affect tropical cyclones (TC) and severe storms (Bertrand et al., 2020) which have a significant impact on fisheries (Reid, 2000) and aquaculture and these are weak globally but can be severe regionally especially across tropical region. Simply, ENSO events impact habitats, migration patterns and trophic webs, thus their effects may experience time lags before being felt via, for instance, changes in fishing rates, and alters climate, weather patterns as well as oceanic conditions and

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productivity across the globe through atmospheric and oceanic teleconnections (Bertrand et al., 2020) by the walker circulation and a Kelvin wave response in the high troposphere (Joly and Voldoire, 2008). The major influence on interannual variation in TC frequency is dynamic controls on its formation, the strongest thermodynamic control is relative humidity (RH) (Collins, 2007). The most vulnerable climatic region for the resent EN are shown on figure 6a and 6b.

7. The impact of ENSO on Climatology of Rwanda

In this section we only consider the effect on Rwanda climatology mainly Rainfall variation, minimum and maximum temperature as the resulting effect of strong LN event and very strong EN event as mentioned on figure 14 and table 2 and the result are expressed in term of annual averaged data.

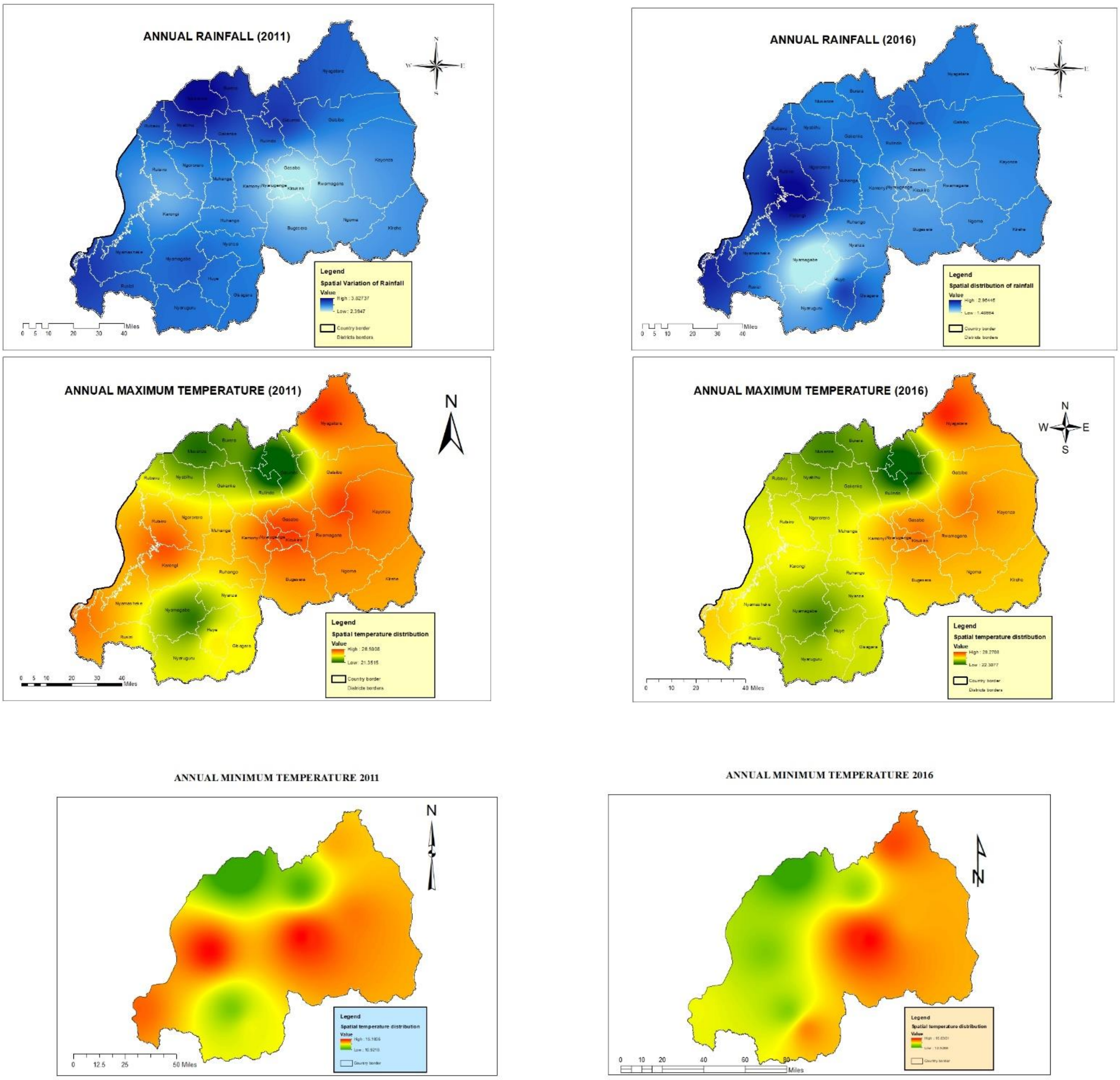

Figure 14. The annual Spatial distribution of Rainfall and maximum temperature for the strong EN and LN episode

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Table 1. The annual mean of rainfall, minimum and maximum temperature

Annual mean values for each station										
Site Parameters	Gitega_ Nyarugenge	Kigali_Aero_ Kicukiro	Butare_ Huye	Gikongoro_ Nyamagabe	Rubengera_ Karongi	Kamembe_ Aero_Rusizi	Ruhengeri_ Musanze	Byumba_ Gicumbi	Nyagatare	Kawangire_ Kayonza
Tmin	15.83	15.54	14.15	13.25	15.76	15.07	11.41	12.71	14.64	14.97
Tmax	27.14	27.25	25.25	23.39	26.79	26.15	23.52	22.04	27.67	27.37
Rainfall	-	2.63	2.803	3.02	2.95	2.99	3.02	2.37	-	-

Table 2. The ENSO years episode

ENSO episode						
EN episode				LN episode		
Weak-12	Moderate-7	Strong-5	Very strong-3	Weak-10	Moderate-4	Strong-7
2004-2005	1986-1987	1987-1988	1982-1983	1983-1984	1995-1996	1988-1989
2006-2007	1994-1995	1991-1992	1997-1998	1984-1985	2011-2012	1998-1999
2014-2015	2002-2003		2015-2016	2000-2001		1999-2000
2018-2019	2009-2010			2005-2006		2007-2008
2019-2020				2008-2009 2016-2017		2010-2011
				2017-2018		

Table 3. The basic statistics for the data

Rainfall										
Site Parameters	Gitega_ Nyarugenge	Kigali_Aero_ Kicukiro	Butare_ Huye	Gikongoro_ Nyamagabe	Rubengera_ Karongi	Kamembe_ Aero_Rusizi	Ruhengeri_ Musanze	Byumba_ Gicumbi	Nyagatare	Kawangire_ Kayonza
Minimum	-	1.299	1.479	1.405	1.816	2.164	1.353	0.9781	-	-
1st quartile	-	1.885	2.505	2.601	2.179	2.677	2.746	2.2627	-	-
Median	-	2.124	2.721	2.871	2.503	3.117	3	2.537	-	-
Mean	-	2.146	2.744	2.829	2.499	3.094	2.985	2.4999	-	-
3rd quartile	-	2.319	3.044	3.166	2.825	3.441	3.122	2.726	-	-
Maximum	-	3.293	3.497	3.571	3.4	4.279	4.008	3.5589	-	-
Maximum temperature										
Site Parameters	Gitega_ Nyarugenge	Kigali_Aero_ Kicukiro	Butare_ Huye	Gikongoro_ Nyamagabe	Rubengera_ Karongi	Kamembe_ Aero_Rusizi	Ruhengeri_ Musanze	Byumba_ Gicumbi	Nyagatare	Kawangire_ Kayonza
Minimum	25.95	25.98	24.25	22.63	25.3	25.55	22.65	21.27	26.37	26.04
1st quartile	26.65	26.78	24.81	22.98	26.27	25.94	23.07	21.61	27.04	26.87
Median	26.93	27.03	25.06	23.27	26.52	26.12	23.46	21.95	27.29	27.1
Mean	26.93	27.04	25.07	23.25	26.53	26.11	23.35	21.84	27.33	27.07
3rd quartile	27.2	27.35	25.26	23.48	26.85	26.34	23.6	22.06	27.67	27.38
Maximum	27.68	28.14	25.66	24.14	27.26	26.66	24.09	22.39	28.27	27.93
Minimum temperature										
Site Parameters	Gitega_ Nyarugenge	Kigali_Aero_ Kicukiro	Butare_ Huye	Gikongoro_ Nyamagabe	Rubengera_ Karongi	Kamembe_ Aero_Rusizi	Ruhengeri_ Musanze	Byumba_ Gicumbi	Nyagatare	Kawangire_ Kayonza
Minimum	15.18	14.92	13.49	12.65	13.67	13.77	10.92	12.18	14.1	14.42
1st quartile	15.61	15.35	13.91	13.03	15.48	14.89	11.25	12.53	14.5	14.85
Median	15.82	15.57	14.07	13.21	15.66	15.07	11.38	12.71	14.67	15.02
Mean	15.83	15.61	14.19	13.26	15.6	15.08	11.49	12.8	14.79	15.04
3rd quartile	16	15.75	14.33	13.45	15.92	15.29	11.64	12.93	14.91	15.24
Maximum	16.64	16.63	15.68	13.97	16.55	15.93	12.67	14.03	16.15	15.79

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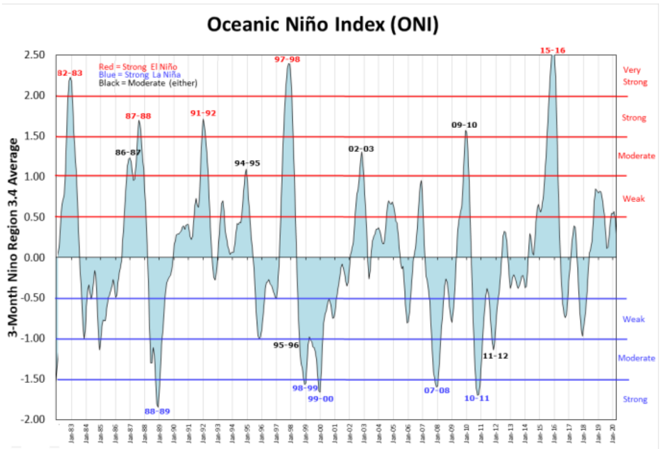

Figure 15. ONI corresponding to the study period interval

The annual mean of minimum temperature, maximum temperature and that of rainfall is mention in the table 1 above, and those values was obtained from the annual average of the years for which no ENSO episode taken place and becomes a key to identify the change caused by ENSO to the annual mean values as shown in table 4. The annual mean profile for the analysed parameters are named figure 16, 17 and 18, the abbreviation shown on the legend represent different data collection sites where G: Gitega-Nyarugenge, Ki: Kigali-Aero-Kicukiro, H: Butare-Huye, N: Gikongoro-Nyamagabe, K: Rubengera-Karongi, Ka: Kamembe-Aero-Rusizi, R: Ruhengeri-Aero-Musanze, B: Byumba-Gicumbi, Ny: Nyagatare, Kw: Kawangire-Kayonza. Generally the annual mean maximum temperature at Nyagatare was mostly the highest while the lowest is at Kamembe-Rusizi. For both maximum and minimum temperature generally, there was a sequence of increasing and decreasing at the most data collection station and become small variation on minimum temperature, this is due to the driving factor of temperature which are seasonal and topography based and do not varies easily, but on rainfall there is no clear sequence as its driving factor are more and varies daily.

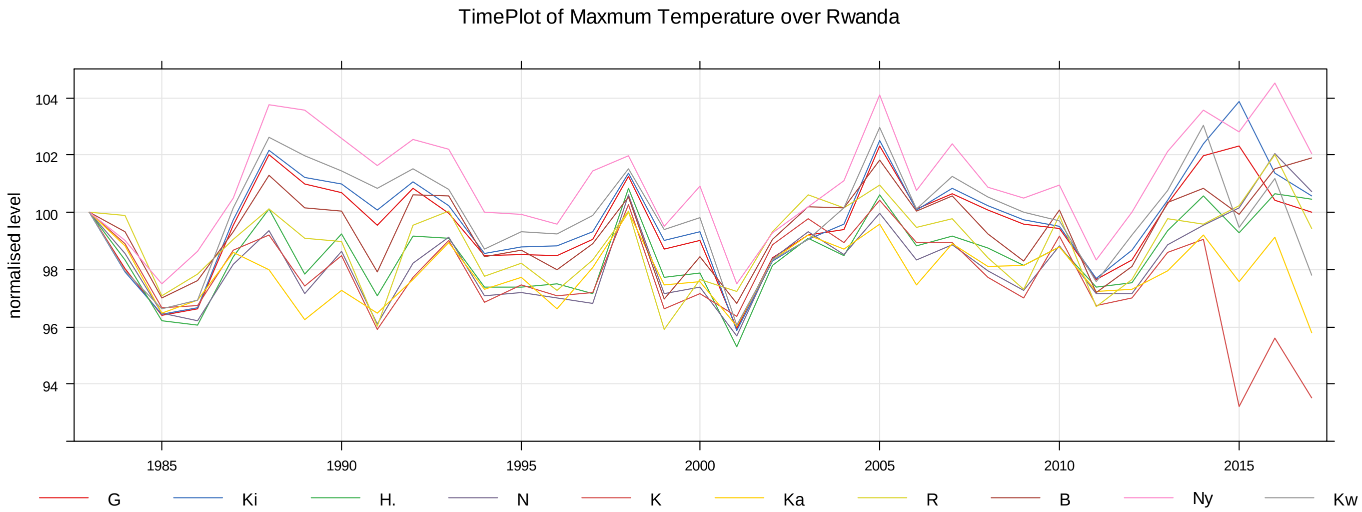

Figure 16. The annual mean maximum temperature profile.

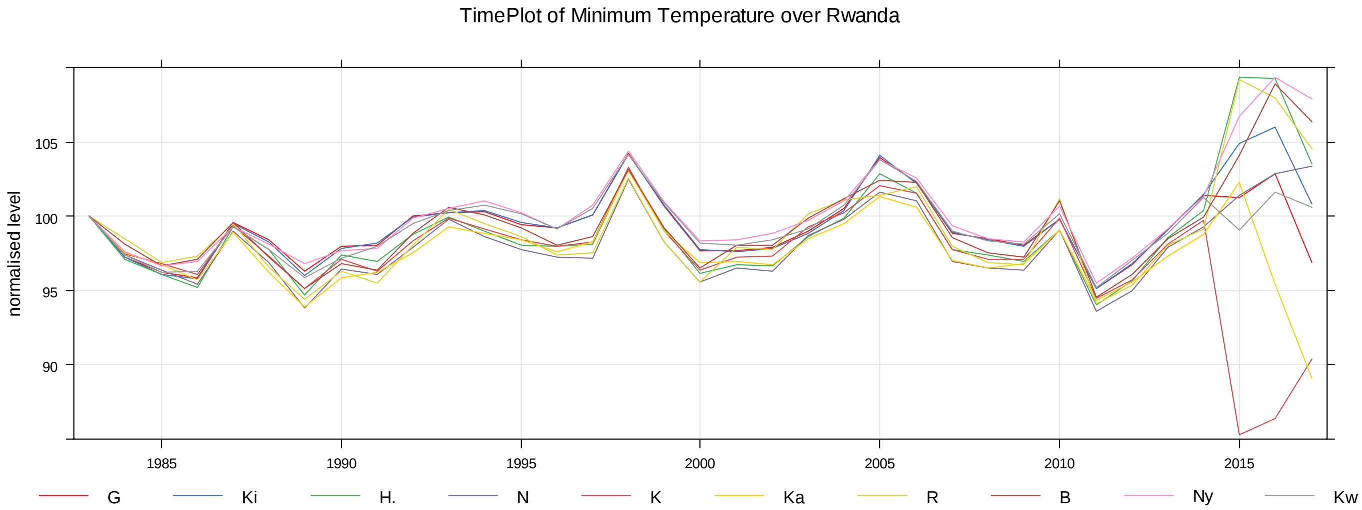

Figure 17. The annual mean miniimum temperature profile.

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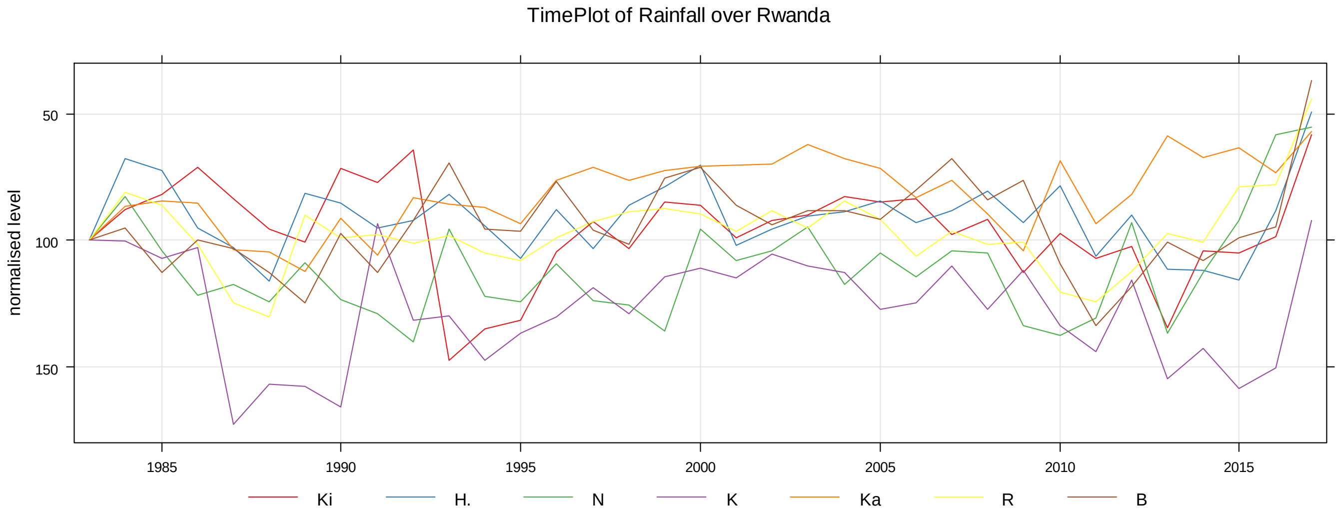

Figure 18. The annual mean rainfall profile.

Table 4. Variation over Rwanda

Episode	Years	Variation
Maximum temperature		
Episode	Years	Variation
EN	1983	0.023
EN	1997-1998	-0.034
EN	2015-2016	0.009
LN	1988-1989	-0.124
LN	1998-1999	-0.136
LN	1999-2000	-0.434
LN	2007-2008	-0.058
LN	2010-2011	-0.378
Minimum temperature		
Episode	Years	Variation
EN	1983	0.109
EN	1997-1998	0.394
EN	2015-2016	0.427
LN	1988-1989	-0.317
LN	1998-1999	0.449
LN	1999-2000	-0.044
LN	2007-2008	-0.109
LN	2010-2011	-0.186
Rainfall		
Episode	Years	Variation
EN	1983	-0.480
EN	1997-1998	-0.913
EN	2015-2016	-1.894
LN	1988-1989	0.522
LN	1998-1999	-1.579
LN	1999-2000	-3.065
LN	2007-2008	-1.916
LN	2010-2011	1.510

8. Conclusion

The aim of this study was achieved, we clearly identify generally ENSO phenomenon and its impact on climatology of Rwanda. The minimum and maximum temperature was affected by ENSO where the annual mean minimum temperature was increased during EN and decreased during LN episode except 2015-2016 and this was similar to the annual mean maximum temperature with an exception of EN took place since 1997-1998 where maximum temperature was decreased as shown by table 4. Even If there are other factors that may determine temperature change like the geographic location and topography of Rwanda, where at the equatorial zone there are only alteration of two season (dry and wet), but this study also show that EN and LN events was proportional to the annual increase of temperature and annual decrease of temperature respectively. For annual mean rainfall this study shows that there was no direct effect of ENSO and rainfall in Rwanda but on this parameter there is other factors to be involved not only ENSO. The others factors involving in rainfall variability in Rwanda include the Inter Tropical Convergence Zone (ITCZ), subtropical anticyclones, regional topography etc. Thus the only one factor cannot be enough to determine rainfall variability in Rwanda.

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