A NOTE ON AIR TEMPERATURE AND PRECIPITATION VARIABILITY AND EXTREMES OVER ASMARA: 1914 – 2015

Short title: Air temperature and precipitation variability in Asmara, Eritrea

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ABSTRACT

Meteorological series (daily precipitation, minimum and maximum air temperature) for Asmara (Eritrea) for the last hundred years (1914 – 2015) are analysed. The data were quality controlled and homogenized using publicly available data from surrounding countries as well as newly recovered data from twelve stations in Eritrea. Overall, the Asmara data showed a consistent pattern and there were no outliers outside of four standard deviations from the corresponding reference. Climate indices were calculated using the program RClimDex. Overall, eight indices for description of the air temperature data and ten for precipitation data were calculated. The analyses of averages and indices reveal large climatic variations in the central highlands of Eritrea. The results indicate significant changes in air temperature since 1943, with daily minimum and maximum air temperature increasing at a similar rate of 0.22 and 0.19 ^{o}C dec^{-1}, respectively. The diurnal air temperature range shows a non-significant decreasing trend over the study period. No significant variation was found in the annual total and the seasonal precipitation over the last century. Significant trends were detected for some daily precipitation indices, although the lack of reference series prevents an evaluation of their reliability.

Key words: Climate extremes; climate variation; Eritrea; RClimDex

1. INTRODUCTION

Studies of climate change are vital and timely for Eritrea since 80% of its population depends on farming and livestock, which are especially sensitive to perturbations in the climate system (IPCC, 2007). Over the years, climate change related studies were undertaken mainly at a regional level that includes Eritrea, using meteorological data (Camberlin and Philippon, 2002; Omondi *et al*., 2012a, 2012b), models (Anyah and Qiu, 2012) and high-resolution satellite data (Brant *et al*., 2012) along with other countries of the Greater Horn of Africa (GHA). However, these studies are limited to provide knowledge regarding the past, present and future patterns of climate in the GHA (Omondi *et al*., 2013). In this region there are inadequate *in situ* data for individual countries, insufficient monitoring networks, gaps in the records, a general decline in the number of stations, chronic under-funding, differences in processing and quality control, and differences in data policies (WMO, 2003; Omondi *et al*., 2013).

The GHA countries have undertaken their respective climate change studies in order to fill the gap and understand the trends of climate change at the national level. In particular, the trends in extreme climate events have recently received much attention because extreme climate events are more sensitive to climate change than their mean values (Katz and Brown, 1992). The climate change studies undertaken for Ethiopia (Seleshi and Zenke, 2004; Seleshi and Camberlin, 2005; Cheung *et al*., 2008), for rainfall and air temperature variability over a century in

Addis Ababa (Conway et al. 2004), and for Kenya (Christy *et al*., 2009) highlands are particularly important as regional references for this study.

The aim of this study is therefore to investigate the variability and change of climate and climate extremes over the central highlands of Eritrea and compare with regional climate variability over the last several decades. A comprehensive description of the study area, data source and procedures for verification of data quality control and homogeneity, and programs used for determining the variability and extreme climate trends are presented in the material and methods section. The analysed results are discussed with subsections for air temperature and precipitation to elaborate on the variability and trend of the extreme indices over the study period. Finally, conclusions are drawn for periodic update and integration of the variability of air temperature and rainfall records regionally and ultimately globally.

2. DATA AND METHODS

2.1 Description of the study area

The study area, the central highlands of Eritrea, ranges from 1500 to 3000 m in elevation and dissects the country into eastern and western lowlands (Figure 1). The eastern lowland is a flat desert area bordering the Red Sea with an elevation change from 100 m below sea level to 500 m above. The western lowland with a semi-arid climate is approximately 500 to 1500 m in elevation. In between, the eastern and western escarpments are located adjacent to the central highlands with a subtropical climate.

In the central highlands, mixed rain-fed farming and livestock-keeping is the main means of livelihood. Therefore, the study of climate variability is essential for the central highlands, which is already under high land use pressure due to the intense population concentration and limited arable land that has been exploited for generations.

2.2 Data sources

We analyse the data series of daily precipitation (1914-2015) and maximum/minimum air temperature (1943-2015) for Asmara (Figure 1: 15° 17' 33.47'' N, 38° 54' 16.84''E and 2321 m.a.s.l.). The series are the result of the combination of three records:

- 1914-1942: Italian colonial data published by Fantoli (1966) – precipitation only;
- 1943-1984: Asmara record in the GHCN (Global Historical Climatology Network) - daily database (Menne *et al*., 2012); and
- 1985-2015: Asmara airport station.

A weather station has been operating in Asmara at least since 1890 (Fantoli, 1966), although with numerous interruptions in the observations. Air temperature data before 1943 are currently available with monthly resolution or in the form of climatological summary only and are not analysed in this work.

Both air temperature and precipitation series are rather complete: the fraction of missing data is 1.2% for maximum air temperature, 1.8% for minimum air temperature, and 2.6% for precipitation (in particular, 1941-1942 data are missing). We did not fill in missing data on the daily scale.

We also analyse the precipitation series measured at the station of Afdeyu (Figure 1: 15^{o} 29' 56.71'' N, 38^{o} 51'53.71''E, 2429 m.a.s.l.), established in mid-1984 to study soil conservation and land use in the central Eritrean highlands (Hurni, 1990; Hurni *et al.*, 2016) in collaboration with the University of Bern (Switzerland). This station is located about 20 km north of Asmara.

To homogenize the Asmara series, we employed additional monthly data series as reference. The reference series for air temperature (monthly means of daily maximum and minimum air temperatures) were obtained from the ISTI (International Surface Temperature Initiative) merged database (Rennie *et al.*, 2014). They consist of two stations in Eritrea (Massawa and Assab), plus over 100 stations in the surrounding countries of Djibouti, Ethiopia, Saudi Arabia, Sudan, and Yemen. Details on these series are provided by the ISTI online inventory (ftp://ftp.ncdc.noaa.gov/pub/data/globaldatabank/monthly/stage3/recommended/results/INVENTORY_monthly_merged_stage3). A map of the stations is included in the Supplementary Material (Figure S1). Note that the series of Massawa and Assab end in 1987, therefore the data from Asmara and Afdeyu used in this paper represent the present in Eritrea.

The reference series for precipitation (monthly totals) were obtained from two sources:

- the GHCN database (Lawrimore *et al*., 2011): six series in Eritrea (Nacfa, Adi Ugri, Agordat, Ghinda, Adi-Kaih, Keren) and three in Ethiopia (Edaga Hamus, Adigrat, Axum), all within 200 km from Asmara;

- data for 11 stations in Eritrea from Fantoli (1966); these include the monthly counts of wet days (i.e., number of days with measurable precipitation). The details for these series can be found in Table S1 in the Supplementary Material.

The series of Afdeyu constituted an additional reference (the only one with wet day information for recent decades).

2.3 Quality control

Data quality control for the series of Asmara and Afdeyu is undertaken as a prerequisite for the calculation of indices used to identify incorrect outliers that influence the indices calculation and their trends. Data quality control and calculation of the indices employ the computer program RClimDex. As described by Zhang and Yang (2004) in the first run the software identifies:

1) Erroneous air temperature and precipitation data (e.g., negative precipitation, daily maximum air temperature less than or equal to minimum air temperature);

2) Potential outliers, which have to be manually checked, validated, corrected or removed. For air temperature, they are defined as values outlying a user-defined threshold determined by a mean plus/minus a number of standard deviations. In this study, the default value (four standard deviations) has been chosen as the threshold for quality control of the data;

3) Finally, through generation of data plots, data were visually inspected as a whole. This allowed for an alternative check for erroneous data values.

As a result, the computer program RClimDex identified few air temperature data where the maximum air temperature was less than the minimum air temperature and accordingly the correction was made manually. Equally, there were no outliers using the default value (four standard deviations) as the thresholds for quality control. The generation of data plots showed a consistent pattern within bound range for both minimum and maximum air temperatures.

The reporting resolution of the temperature observations before July 1965 was 1 °C. Random white noise between -0.5 and 0.5 °C was added to those observations in order to make them comparable with later observations, which have a reporting resolution of 0.1 °C.

2.4 Homogenisation

2.4.1 Craddock's test

We checked data homogeneity visually by applying the Craddock test (Craddock, 1979). This test is based on cumulative differences between the candidate series and a certain number of rescaled reference series. Given a candidate time series to be tested $\mathbf{x_c(t_1 \ldots t_n)}$ and a well correlated reference series $\mathbf{x_r(t_1 \ldots t_n)}$, the Craddock's series is defined as:

$$\mathbf{c(t_i) = c(t_{i-1}) + \overline{x_c} - \overline{x_r} + x_r(t_i) - x_c(t_i)}\#(\mathbf{1})$$

with $\mathbf{c(t_1)}$ equal to zero. For precipitation amounts, the equation becomes:

$$\mathbf{c(t_i) = c(t_{i-1}) + {}^{\overline{x_c}}/_{\overline{x_r}} \cdot x_r(t_i) - x_c(t_i)}.\#(\mathbf{2})$$

One can assume that, if both series are homogeneous, $\mathbf{x_c} - \mathbf{x_r}$ (or $\mathbf{x_c}$ / $\mathbf{x_r}$ when analysing precipitation amounts) is constant in time except for some random noise; *c* will then randomly oscillate around zero. If, however, either $\mathbf{x_c}$ or $\mathbf{x_r}$ are inhomogeneous (i.e., their mean has a sudden change), **c** will show a sharp change in the slope, that is easier to detect visually than a change in the mean, in correspondence to the inhomogeneity (also called the breakpoint).

Since either one of the series could be the cause of the breakpoints, it is necessary to plot **c** several times, each time using a different reference series. A breakpoint can be assigned to the candidate series if it is detected consistently using multiple reference series.

The Craddock test allows good accuracy in the detection of breakpoints. It has better performances than most of the other breakpoint detection tests commonly used in climate science (Venema *et al*., 2012), at the cost of a larger amount of manual work that makes it unsuitable for large datasets.

The following data series were analysed for breakpoints: maximum, minimum, and average air temperature, daily air temperature range, total precipitation, and number of wet days, all with monthly resolution.

Our implementation of the Craddock test automatically rejected those reference series that had a Pearson's correlation coefficient less than 0.6 or less than five years in common with the candidate series.

The Craddock test also allowed the detection of additional systematic quality problems in the series of Asmara. In particular, precipitation in the years 1936 to 1938 was largely overestimated both in quantity and frequency of wet days, when compared to nearby stations. Therefore, those years were removed from the analysed series. Similarly, doubtful measurements were found in the years 1978 to 1980; in this case, however, the geographical distances of the available reference series were too large to support the removal of the data, hence no action was taken.

We identified three breakpoints in the maximum air temperature series (1959, 1996, 2007), six breakpoints in the minimum air temperature series (1964, 1984, 1988, 1992, 1996, 2007), and two breakpoints (1992 and 1996) in the precipitation series.

We did not find breakpoints in the number of wet days. However, there is a lack of suitable reference series for the number of wet days between 1953 (the end of colonial data) and 1985 (the start of the Afdeyu series), meaning that we cannot verify the homogeneity of daily precipitation indices during that period. Moreover, we do not have any information on instrumentation and station relocations.

2.4.2 Adjustments

We estimated daily adjustments for the Asmara air temperature series from manually selected reference series after fitting a 9th order polynomial to the monthly adjustments (the median of the adjustments estimated from each reference series was used). The adjustments were applied backwards, i.e., assuming that the most recent homogeneous sub-period does not need correction. Figure 2 presents an example of the adjustments for the 1943-1963 period in the minimum air temperature series; these adjustments suggest that the thermometer was located at an elevated position (terrace or roof), as also reported by Fantoli (1966).

Precipitation measurements in Asmara were underestimated during the period 1993-1996 and were multiplied by a correction factor of 1.54. This correction was estimated using the data series from Afdeyu.

We created a nearly complete monthly precipitation series for Asmara by filling in the missing months in the period 1931-1953 with data from the Godaif colonial station (approximately today's airport location), multiplied by a correction factor of 1.21 calculated from the parallel observations of the two stations.

2.5 Variability and trend analysis

The annual air temperature and precipitation variability analysis was undertaken by plotting the data series over the years of the study period. A linear regression was then fitted and p-values calculated. The slope of the regression line was considered as an indicator of the rate of change and the changes were assumed to be significant at the 5% probability level. The climatic indices are calculated using the RClimdex software (Klein-Tank *et al*., 2009), which is widely used for trend analysis (Aguilar *et al*., 2005; Alexander *et al*., 2006; New *et al*., 2006; Omondi *et al*., 2013; Mekasha *et al.*, 2014). Generally, the software provides 27 climate indices but in this study eight indices were selected for description of the air temperature data and ten for precipitation data (Table 1). These indices were chosen since these are appropriate for the local arid and semi-arid climate conditions.

3. RESULTS AND DISCUSSION

3.1 Precipitation

The central highland of Eritrea has four distinct seasons: namely winter (locally called *hagay*) from December to February (DJF), spring (*ayet*) when the short rainfall (*azmera*) occurs from March to May (MAM), summer (*keremti*) the main rainy season from June to August (JJA); autumn (*kewea*) from September to

November (SON). The rainfall regime is bimodal (Figure 3), where on average the long and short rainfall periods account for 76% and 17% respectively of the total annual rainfall. The mean annual rainfall of Asmara for 1914 to 2015 is 509 mm.

3.1.1 Total precipitation change

The annual precipitation exhibits large interannual variability over the last hundred years. However, there are no statistically significant changes for both the short rainy (MAM) and main rainfall seasons (JJA) for the stations of Asmara and Afdeyu (Figure 4). This result is consistent with the regional findings indicating that there are no significant changes or trends at the national or watershed level such as in Ethiopia (Conway *et al*. 2004; Cheung *et al*., 2008; Hadgu *et al*., 2013) and Kenya (Rao *et al*., 2011). In SON there are a few light rains in Afdeyu due to its location and proximity to the eastern escarpment where the winter period starts in November and becomes very foggy and humid (Fessehaye *et al*., 2015).

3.1.2 Trends in precipitation indices

Four of the precipitation indices (SDII, CDD, CWD and R10) indicate statistically significant trends for Asmara. The remaining indices did not indicate significant trends for both Asmara and Afdeyu stations over the study period (Table 2). The simple daily intensity index (SDII) and consecutive dry days (CDD), which are both the meteorological drought indicators for dry climates (Wanders et al., 2010), increased statistically significantly over the last hundred years for Asmara whereas the consecutive wet days (CWD) and number of heavy precipitation days (R10) decreased significantly (Figure 5).

Overall, this implies the number of rainfall days is decreasing but the intensity of rainfall per given rainy day is increasing. Figure 5 shows that these trends are mainly caused by a sudden change around 1980, which could be a sign of residual inhomogeneity in the series (no daily reference series are available for that period). The indices calculated from the series of Afdeyu agree well with those for Asmara over the last 30 years, with no significant trend found (Table 2).

3.2 Air temperature

The mean annual air temperature for Asmara over the study period is 15.9 °C and the coldest season is from December to February with an average minimum air temperature of 4.2 °C. The warmest season is from March through May, with an average maximum air temperature of 25.8 °C (Figure 6).

3.2.1 Air temperature change

The annual minimum air temperature trend for Asmara (0.22 °C dec^{-1}) indicates a statistically significant ($p < 0.05$) increase. Similarly, the maximum air temperature trend for Asmara (0.19 °C dec^{-1}) indicates a statistically significant ($p < 0.05$) increase (Figure 6). In addition, the minimum and maximum air temperatures indicates a statistically significant ($p < 0.05$) increase throughout the four seasons (Figure 6). Regionally, observations in Addis Ababa, Ethiopia indicated an increasing minimum air temperature (0.4 °C dec^{-1}) at a greater rate than the maximum air temperature (0.2 °C dec^{-1}) from 1951 to 2002 (Conway *et al*. 2004). Similarly, in Kenya statistically significant upward trends in minimum air temperature were reported for the highlands region after spatially interpolating air temperature at 60 stations across the country (Christy *et al*., 2009).

Globally, there is a greater increasing trend in annual minimum air temperature (0.204 °C dec^{-1}) than the maximum air temperature (0.141 °C dec^{-1}) during the latter half of the 20th century (Easterling *et al*., 1997; Vose *et al*., 2005).

3.2.2 Trend in warm indices (SU25, TXx, TNx and TMaxMean)

Three of the warm air temperature indices indicate a statistically significant increasing trend (Table 3). The number of warm days (SU25) where the daily maximum air temperature is greater than 25 °C, has increased sharply for Asmara (Figure 7). A similar pattern was observed regionally in Kenya and globally at large (Omondi *et al*., 2013). In addition, the monthly maximum value of daily minimum air temperature (TNx) and annual mean of the daily maximum air temperatures (TMaxMean) indicates a significant increasing pattern.

The extreme droughts of 1972–1973, 1983–1984 and 1991–1992 were continental in nature and stand unique in the available records (Masih *et al*., 2014). For these extreme drought years, the annual precipitation was very low particularly in the main rainfall season JJA (Figure 6). Likewise, the air temperature peaks in these drought periods (Figure 5), which further aggravated the drought situation. Particularly, the 1984 drought year showed the highest annual average air temperature (17.0 ^{o}C) after the year 2015 (17.1 ^{o}C), which is claimed to be the hottest year globally (Tollefson, 2016). Similarly, the precipitation for 1984 (291 mm) was below the long-time average (363 mm) for the precipitation period (JJA).

3.2.3 Trend in cold indices (TXn, TNn and TMinMean)

The monthly minimum of daily maximum air temperatures (TXn) and annual mean of the daily minimum air temperatures (TMinMean) indicates a statistically significant increasing pattern. However, the monthly minimum value of daily minimum air temperature (TNn) indicated a decreasing trend (Table 3). Overall, the warm extremes are increasing while cold extremes indicate a decreasing trend (Table 3), therefore these trends indicate a marked warming pattern over the study period.

3.2.4 Diurnal air temperature range (DTR)

The diurnal air temperature range indicates a decreasing trend over the analysis period, although not statistically significant (Figure 8). The air temperature difference between the daily maximum and minimum air temperatures is decreasing slightly since the minimum air temperature is increasing at a relatively faster rate (0.22 °C dec^{-1}) than the maximum air temperature (0.19 °C dec^{-1}).

Similarly, the analysis of global maximum and minimum air temperatures indicates a decreasing trend of DTR for many parts of the world since the minimum air temperature increased at a faster rate than maximum air temperature during the latter half of the 20th century (Easterling *et al*., 1997; Vose *et al*., 2005; Thorne *et al.*, 2016). On the one hand, decreased DTR may be the result of decreased solar radiation and increased cloud cover (Hargreaves and Samani, 1982; Wang and Dickinson, 2013). On the other hand, the global decrease of DTR is compatible with the increased concentration of greenhouse gases (Lindvall and Svensson, 2015).

4. CONCLUSIONS

The central highlands of Eritrea has experienced a change in climate over the last hundred years. In particular, the minimum air temperature (0.22 ^{o}C dec^{-1}) and the maximum air temperature (0.19 ^{o}C dec^{-1}) have increased at a similar rate. Generally, these results are similar to other countries within the GHA.

Overall, the total annual and seasonal precipitation of both the small (AMJ) and long rainfall (JAS) seasons did not indicate statistically significant variation. However, the simple daily intensity index (SDII) and consecutive dry days (CDD) increased statistically significantly over the last one hundred years. The significant increase in CDD reflects drought incidence increase since CDD is one of the meteorological drought indicators for dry climates. By the same token, both the consecutive wet days (CWD) and number of heavy precipitation days (R10) decreased significantly.

This implies that the frequency of rainfall is decreasing and the daily intensity of rainfall is increasing. These results, however, necessitate further investigation as they could be affected by artificial inhomogeneities. For the last 30 years, when data homogeneity can be verified with more confidence, no significant change in daily precipitation indices were found.

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List of figures

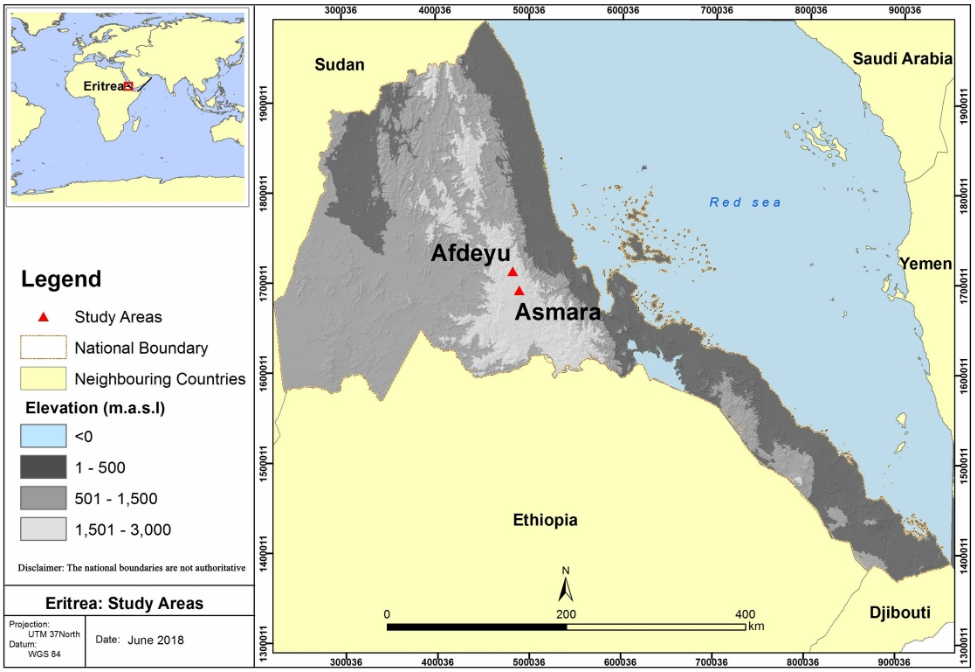


Figure 1: Map of the study area.

297x210mm (300 x 300 DPI)

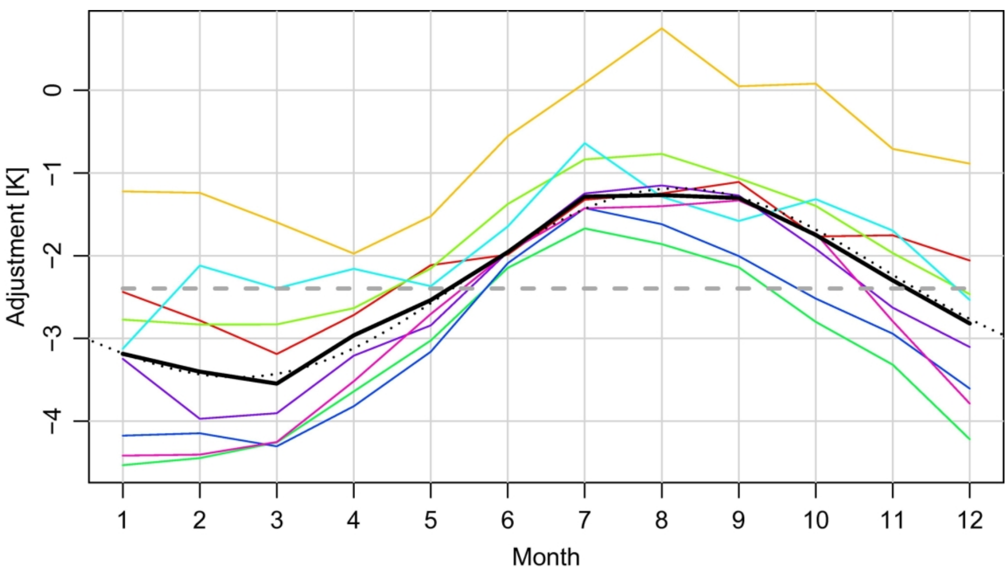
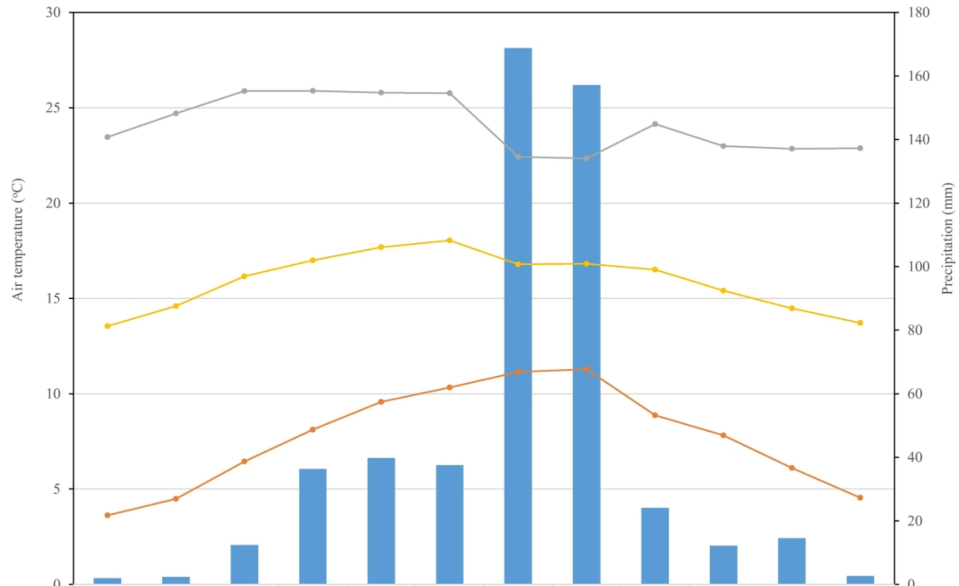


Figure 2: Adjustments to the minimum air temperature series of Asmara for the period 1943-1963. The continuous lines are monthly estimations from single reference series, the thick black line is their median, the dotted line represents the daily adjustments, the horizontal dashed line is the annual average of the adjustments.

172x95mm (300 x 300 DPI)



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
PRCP	2	2	12	36	40	37	169	157	24	12	15	3
Tmin	4	4	6	8	10	10	11	11	9	8	6	5
Tmax	23	25	26	26	26	26	22	22	24	23	23	23
Tave	14	15	16	17	18	18	17	17	17	15	14	14

Figure 3: Average minimum, maximum, and mean air temperature (°C) and precipitation (mm) for Asmara for the study period (1914 to 2015).

235x166mm (300 x 300 DPI)

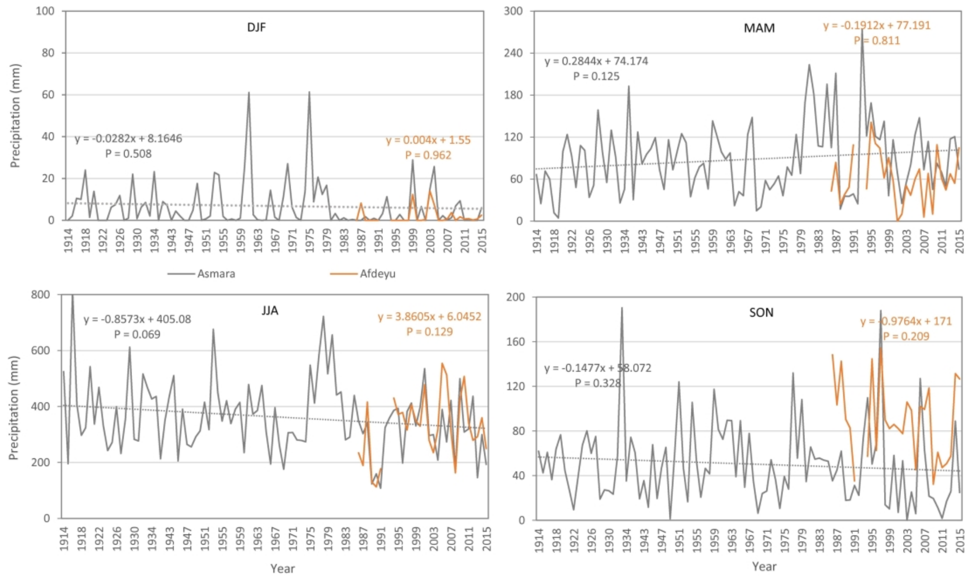


Figure 4: Seasonal precipitation (mm) for Asmara and Afdeyu for the study period.

255x151mm (300 x 300 DPI)

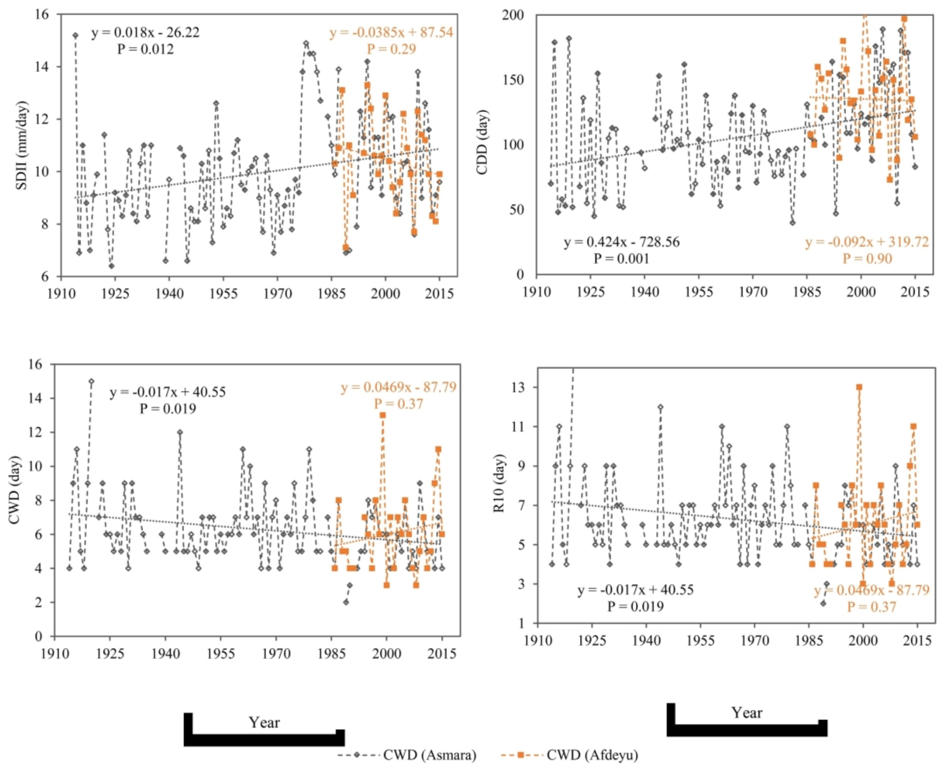


Figure 5: Precipitation indices (SDII, CDD, CWD and R10) that indicate significant variation.

216x166mm (300 x 300 DPI)

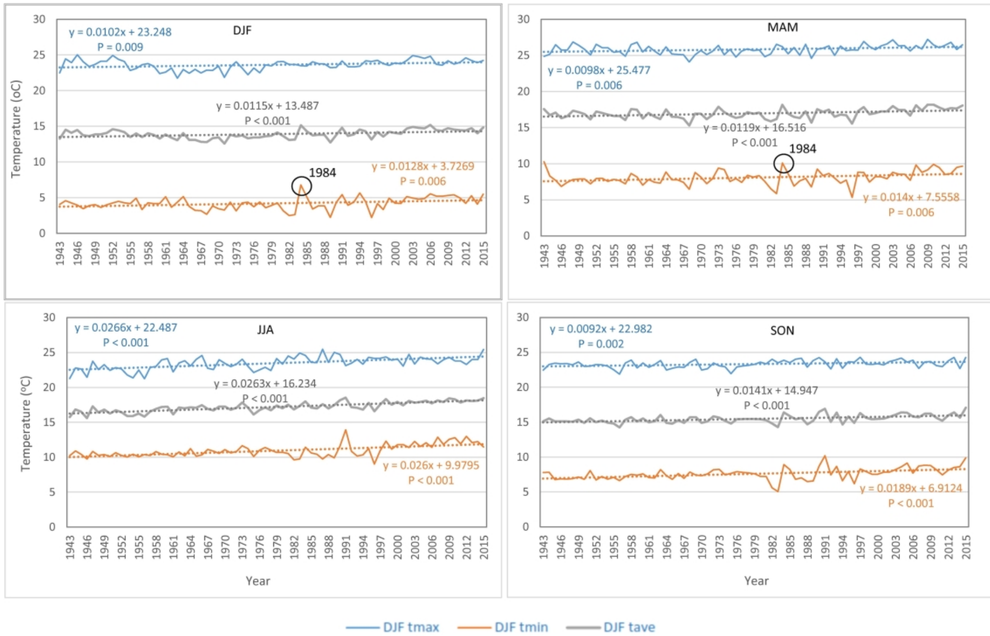


Figure 6: Seasonal air temperature (°C) variability for Asmara for the study period.

257x164mm (300 x 300 DPI)

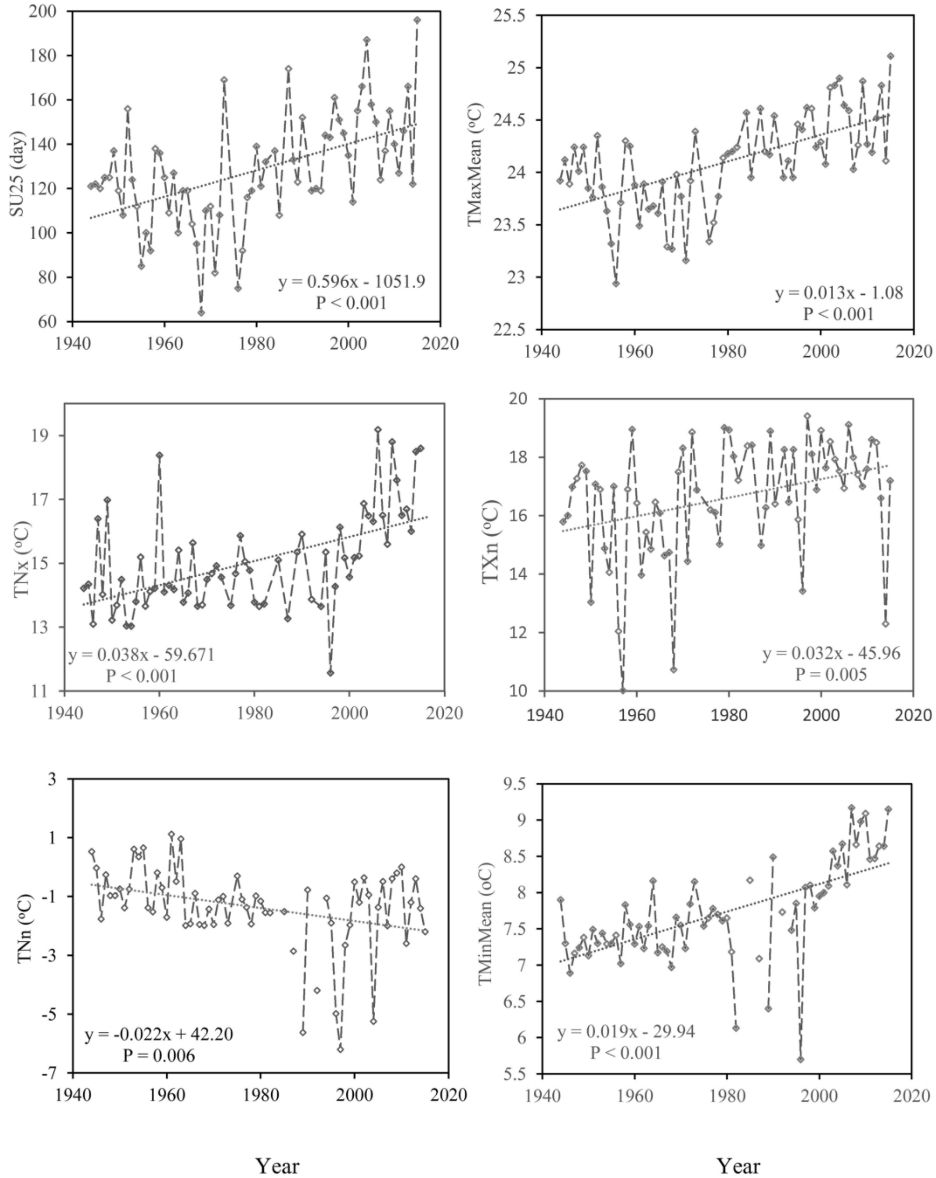


Figure 7: Asmara air temperature indices that indicate statistically significant variation.

162x204mm (300 x 300 DPI)

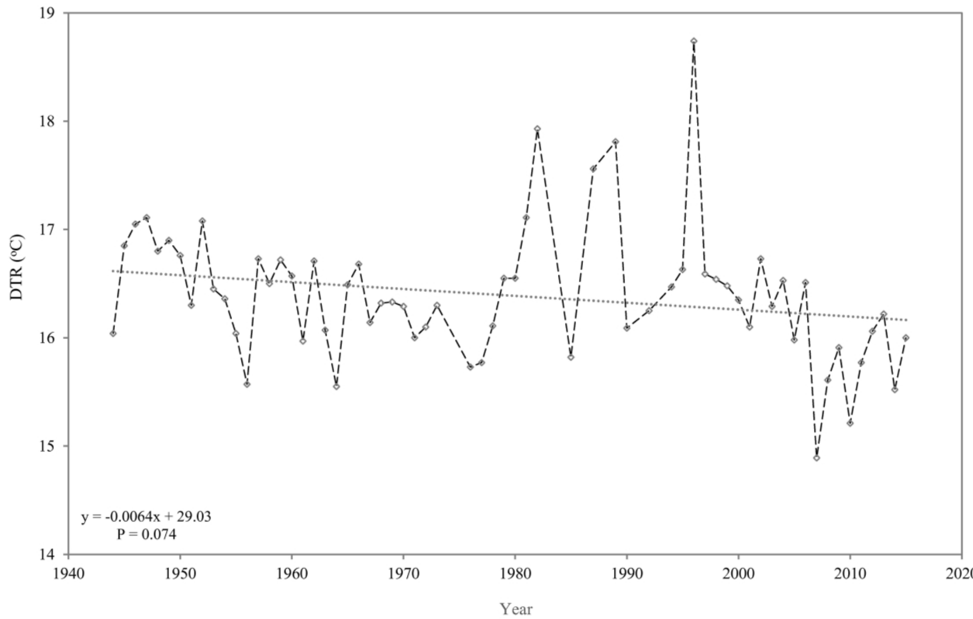


Figure 8: Diurnal air temperature range (DTR) for Asmara for the period 1943 - 2015.

228x143mm (300 x 300 DPI)

Table 1: Definition of air temperature indices

Index	Descriptive name	Definition	Unit
		Warm temperature indices	
SU25	Summer/hot days	Annual count when TX (daily maximum) > 25 ºC	day
TXx	Max Tmax	Monthly maximum value of daily maximum air temperatures	ºC
TNx	Max Tmin	Monthly maximum value of daily minimum air temperatures	ºC
TMaxMean	TMaxMean	Annual mean of the daily maximum air temperatures	ºC
		Cold temperature indices	
TXn	Min Tmax	Monthly minimum value of daily maximum air temperatures	ºC
TNn	Min Tmin	Monthly minimum value of daily minimum air temperatures	ºC
TMinMean	TMinMean	Annual mean of the daily minimum air temperatures	ºC
DTR	Diurnal air temperature range	Monthly mean difference between TX and TN	ºC
		Precipitation indices	
PRCPTOT	Annual total wet-day precipitation (PRCP)	Annual total PRCP in wet days (RR >= 1 mm)	mm
SDII	Simple daily intensity index	Annual total precipitation divided by the number of wet days (defined as PRCP >= 1.0 mm) in the year	mm/day
CDD	Consecutive dry days	Maximum number of consecutive days with RR < 1 mm	day
CWD	Consecutive wet days	Maximum number of consecutive days with RR >= 1 mm	day
RX1day	Maximum 1-day precipitation amount	Monthly maximum 1-day precipitation	mm
RX5day	Maximum 5-day precipitation amount	Monthly maximum 5-day precipitation	mm
R10	Number of heavy precipitation days	Annual count of days when PRCP >= 10 mm	day

R20	Number of very heavy precipitation days	Annual count of days when PRCP >= 20 mm	day
R95p	Very wet days	Annual total PRCP when RR > 95th percentile	mm
R99p	Extremely wet days	Annual total PRCP when RR > 99th percentile	mm

Table 2. Summary of trends (units per decade) and annual averages of the precipitation indices for the two analysed stations

Index	Units	Asmara (1914-2015)			Afdeyu (1985-2015)		
		Indices*	P-Value	Annual average	Indices *	P-Value	Annual average
PRCPTOT	mm	-0.579	0.299	509	2.553	0.337	477
SDII	mm/day	**0.019**	**0.011**	9.96	-0.038	0.288	10.41
CDD	day	**0.424**	**0.001**	105	-0.092	0.902	135
CWD	day	**-0.017**	**0.019**	6	0.047	0.369	6
RX1day	mm	0.060	0.330	51	0.099	0.821	57
RX5days	mm	-0.048	0.704	94	0.33	0.599	95
R10	day	**-0.035**	**0.049**	17	0.028	0.741	15
R20	day	0.001	0.926	7	0.072	0.170	7
R95p	mm	0.146	0.67	118	1.212	0.370	112
R99p	mm	0.182	0.386	35	-0.69	0.487	32

*A trend significant at the 5% level is marked with bold font

Table 3. Trends (units per decade) of warm air temperature indices for the study area in relation to regional and global indices

Index	Unit	Eritrea	Regional		Global
		Asmara	Ethiopia	Kenya	
Warm air temperature indices					
SU25	day	**0.596**	0.11	**0.35**	**0.21**
TXx	ºC	0.009	N/A	N/A	N/A
TNx	ºC	**0.038**	N/A	N/A	N/A
TMaxMean	ºC	**0.013**	N/A	N/A	N/A
Cold air temperature indices					
TXn	ºC	**0.032**	N/A	N/A	N/A
TNn	ºC	**-0.022**	N/A	N/A	N/A
TMinMean	ºC	**0.019**	N/A	**-1.6**	**-0.62**
DTR	ºC	-0.006	0.61	0.22	-0.08

*The regional and global trends are from Omondi *et al*. (2013)

**A trend significant at the 5% level is marked with bold font