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LETTER

Projected climate over the Greater Horn of Africa under 1.5 °C and 2 °C global warming

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Supplementary material for this article is available online

Abstract

We analyze the potential effect of global warming levels (GWLs) of 1.5 °C and 2 °C above pre-industrial levels (1861–1890) on mean temperature and precipitation as well as intra-seasonal precipitation extremes over the Greater Horn of Africa. We used a large, 25-member regional climate model ensemble from the Coordinated Regional Downscaling Experiment and show that, compared to the control period of 1971–2000, annual mean near-surface temperature is projected to increase by more than 1 °C and 1.5 °C over most parts of the Greater Horn of Africa, under GWLs of 1.5 °C and 2 °C respectively. The highest temperature increases are projected in the northern region, covering most parts of Sudan and northern parts of Ethiopia, and the lowest temperature increases are projected over the coastal belt of Tanzania. However, the projected mean surface temperature difference between 2 °C and 1. 5 °C GWLs is higher than 0.5 °C over nearly all land points, reaching 0.8 °C over Sudan and northern Ethiopia. This implies that the Greater Horn of Africa will warm faster than the global mean.

While projected changes in precipitation are mostly uncertain across the Greater Horn of Africa, there is a substantial decrease over the central and northern parts of Ethiopia. Additionally, the length of dry and wet spells is projected to increase and decrease respectively. The combined effect of a reduction in rainfall and the changes in the wet and dry spells will likely impact negatively on the livelihoods of people within the coastal cities, lake regions, highlands as well as arid and semi-arid lands of Kenya, Tanzania, Somalia, Ethiopia and Sudan. The probable impacts of these changes on key sectors such as agriculture, water, energy and health sectors, will likely call for formulation of actionable policies geared towards adaptation and mitigation of the impacts of 1.5 °C and 2 °C warming.

1. Introduction

The landmark 2015 international climate change agreement, reached during the 21st Conference of Parties to the United Nations Framework Convention on Climate Change (UNFCCC) meeting (The Paris Climate Change Agreement) emphasized the need to curb increase in global average temperature to well below 2 °C above the pre-industrial levels and pursue efforts to limit temperature increase to 1.5 °C, so as to avoid adverse impacts of climate change (UNFCCC 2015).

The fifth assessment report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) demonstrated that global warming will not be uniform across different regions. However, the impact of global mean temperature increases at 1.5 °C and 2 °C will be particularly critical in some of the climate change hotspots (IPCC 2014). For example, studies investigating the range of projected changes for the European climate under 1.5 °C and 2 °C global warming found that most of Europe will experience higher warming than global average (Vautard *et al* 2014, Dosio and Fischer 2018). In particular, warming over the land will be larger than over the ocean (IPCC 2013, Byrne and O'Gorman 2016, Dommenget 2009). Such warming is also likely to affect precipitation patterns, especially extreme events, as demonstrated by Fischer and Knutti (2015), who showed that about 18% of moderate daily precipitation extremes over land are attributable to the present 0.85 °C global warming above pre-industrial levels. Africa is one of the most vulnerable continents to climate change due to its high exposure and low adaptive capacity (Ogallo 1989, Ntale *et al* 2003, Omondi *et al* 2009, 2012). Furthermore, it is likely that African land surface temperatures will rise faster than global land average and the rate of increase in minimum temperature will likely exceed that of maximum temperature (IPCC 2014).

Based on analysis of an ensemble of global climate models (GCMs) from the Coupled Model Intercomparison Project Phase 5 (CMIP5), Otieno and Anyah (2013) showed that the projected mean near surface temperature in the northern and southern parts of Greater Horn of Africa (GHA) is likely to increase by 2 °C–2.5 °C and 2 °C–3 °C, respectively, by the middle of the 21st century with respect to 1981–2000. It is also projected that most parts of GHA will likely experience an increase in the number of days with maximum and minimum temperatures reaching at least 2 °C higher than the 1971−2000 averages by the end of the 21st century (Anyah and Qiu 2012).

However, due to their low spatial resolution, GCMs are not able to resolve small-scale processes that are influenced by topographical details, coastlines, and land-surface heterogeneities. Therefore, by using regional climate models (RCMs) to dynamically downscale the results of the global models, added value may be found especially over topography and in the simulation of extreme events (Dosio *et al* 2015) although large discrepancies between GCMs' and RCMs' results can exist especially for the precipitation signal (Dosio and Panitz 2016). In order to foster international collaboration to generate an ensemble of high-resolution historical and future climate projections, the World Climate Research Programme CORDEX (COordinated Regional Downscaling EXperiment) selected Africa as the first target region of study (Giorgi *et al* 2009).

An analysis of the ability of the CORDEX RCMs to simulate present day African climatology was performed by Nikulin *et al* (2012), who showed that most of the RCMs capture the main details of the precipitation climatology, although individual models may exhibit substantial biases. Since then, several studies investigated the future projections of temperature and precipitation based on CORDEX-Africa RCMs (Laprise *et al* 2013, Teichmann *et al* 2013, Giorgi *et al* 2014, Buontempo *et al* 2015, Mariotti *et al* 2014, Dosio and Panitz 2016, Pinto *et al* 2016, Diallo *et al* 2016, Dosio 2017) but these studies analyzed only the climate change at the end of the century, and most of them are based on the results of a small ensemble, or a single RCM. Based on a small subset of CORDEX RCMs, Déqué *et al* 2017 investigated the consequences of a 2 °C global warming on temperature and precipitation over tropical Africa and showed that the temperature increase is above the global average. In their study, it was apparent that heat waves are expected to be more frequent (see e.g. Russo *et al* 2016, Dosio 2017), while changes in mean precipitation remain uncertain despite the fact that extreme precipitation was expected to increase (Déqué *et al* 2017).

In this study, we utilize, for the first time to our knowledge, the whole ensemble of CORDEX-Africa RCMs to analyze the likely changes in patterns of precipitation and temperature means and extremes over the GHA when the projected global mean temperature reaches 1.5 °C and 2 °C above pre-industrial levels.

The paper is structured as follows: section 2 describes the target region of this study; the climate data and the methodology, including the definition of the GWLs' timings and measure of robustness of the climate change signal are described in section 3; results are described in section 4 and concluding remarks in section 5.

2. Overview of study area

This study focuses over the GHA region, comprising Ethiopia, Eritrea, Djibouti, Sudan, South Sudan, Somalia, Uganda, Burundi, Rwanda, Kenya and Tanzania (figure 1). The economy of the region is heavily dependent on rainfall. The region is one of the most drought and flood-prone areas in Africa (Li *et al* 2016), where extreme events have been causing devastating effects on the populations of the region. Local factors such as complex terrain, large inland water bodies

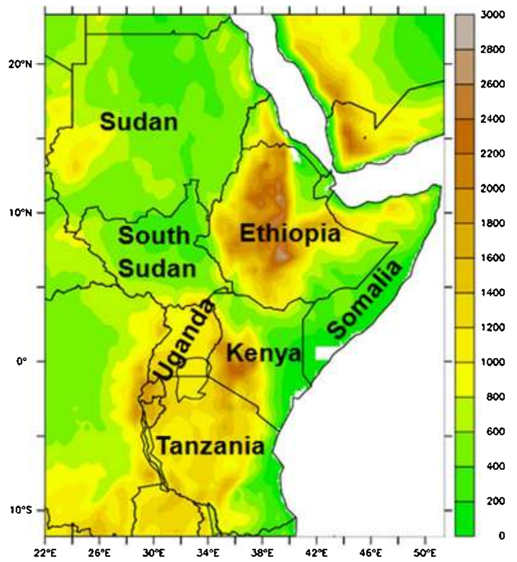

Figure 1. The study area map showing GHA (21.84 E–51.39 E and 11.74S–23.5 N). The color scale shows the topography in meters above sea level.

(Lake Victoria) and land heterogeneity (with the highest peak of Africa, mount Kilimanjaro) and their consequent interactions with large-scale climate forcing mechanisms, contribute to the diverse spatial rainfall patterns over the region. The seasonality of rainfall over the region is strongly linked to the seasonal movement of the inter-tropical convergence zone (ITCZ) (Nicholson 2016a). Areas in the northern and western part of the region, mainly Eritrea, Northern Ethiopia, Djibouti, Northern Uganda, and South Sudan receive most of their rainfall during boreal summer (June to September—JJAS), whereas the southernmost parts of the region (primarily central and southern Tanzania) receive peak rainfall in the boreal winter starting from November to April (NDJFMA). The equatorial parts including Kenya, Northern Tanzania, Somalia and Southern Ethiopia, Rwanda, Burundi and most of Uganda experience two rainfall seasons during March to May (MAM) and October to December (OND), traditionally known as the 'long rains' and 'short rains', respectively. The long rains are the heavier compared to the short rains but the short rains show strong variability due to the El Niño-Southern Oscillation (ENSO) and the Indian Ocean Zonal Mode (IOD) (Nicholson 2015a).

3. Methods and data

The methodologies used to determine levels of global warming, the time when these levels of global warming are reached, and a quantification of the robustness of regional change signals at these warming levels are presented in Nikulin *et al* (2018) of this focus collection. We summarise these methodologies very briefly below, and refer the reader to this publication. We take the average global warming level (e.g. 1.5, 2, 3, 4 degrees) above the mean temperature of some baseline period as global warming levels (GWLs). Although different definitions of GWLs exist in the literature, they all generally start with some pre-industrial (PI) baseline, and use an averaged window period (e.g. 15, 20 or 30 years) to compute departure from the baseline and arrive at the time when the GWL of interest is reached. We take 1861–1890 to define the pre-industrial (PI) period, as it is available across all CMIP5 historical simulations. Then, for each GCM downscaled, the timing of the relevant GWL is defined as the first time the 30 year moving average (centre year) of global temperature is above 1.5 °C or 2 °C compared to pre-industrial. The corresponding 30 year period is then extracted from the downscaling RCM for analysis using 1971–2000 as the control period. This control period is selected as the CORDEX simulations are available only from 1950 and the global warming signal in the region is nonetheless successfully captured using 1971–2000 as the control period (see supplementary material, figure 1S available at stacks.iop.org/ERL/13/065004/mmedia).

There are also many methodologies used to determine the robustness of a climate change signal (Collins *et al* 2013). Here, we consider a climate change signal robust if the following two conditions are fulfilled: (1) more than 80% of model simulations agree on the sign of the change and (2) the signal to noise ratio, i.e. the ratio of the mean to the standard deviation of the ensemble of climate change signals, is equal to or larger than one. The first criterion considers model agreement and the second is a measure of the strength of the climate change signal (with respect to the inter-model variability in that signal). We use both in defining robustness because the first criterion may be fulfilled even in the case of a very small, close to zero change.

In this study, we utilise the CORDEX-Africa runs driven by the RCP8.5. We note that the CMIP5 RCPs were not designed to address GWL concerns, nor to analyze difference between the effects of 1.5° and 2 °C of global warming (James *et al* 2017). Of the existing RCP2.6 GCM simulations, which can be considered as the most appropriate proxy for holding GWL below 2 °C, only 13 CORDEX-Africa simulations have been generated by only three RCMs (see table 1). Furthermore, the RCP8.5 comprises the largest ensemble (25 runs) and may also be considered the most realistic given the current trajectory of greenhouse gases emissions.

We analyzed mean precipitation and temperature fields as well as two extreme indices from the Expert Team on Climate Change Detection and Indices (ETCCDI) (Zhang *et al* 2011), namely consecutive dry days (CDD) and consecutive wet days (CWD). The analysis was performed both on annual and seasonal (MAM and JJAS) time scales. We further analyse the differences in the spatial characteristics of temperature and precipitation as a result of the extra 0.5 °C warming between 1.5 °C and 2 °C.

Table 1. List of the CORDEX Africa RCMs, their driving GCMs and RCPs downscaled by each RCM. Only RCMs -GCM combinations with RCP8.5 were used in study.

AFR-44 CORDEX simulations			
RCM	Driving GCM	RCPs	Period
SMHI-RCA4	CCCma-CanESM2	45, 85	1951–2100
	CNRM-CERFACS-CNRM-CM5	45, 85	1951–2100
	MOHC-HadGEM2 E S	26,45, 85	1951–2099
	NCC-NorESM1 M	26,45, 85	1951–2100
	ICHEC-EC-EARTH	26,45, 85	1951–2100
	MIROC-MIROC5	26,45, 85	1951–2100
	NOAA-GFDL-GFDL-ESM2M	45, 85	1951–2100
	MPI-M-MPI-ESM-LR	26,45, 85	1951–2100
	IPSL-IPSLCM5A-MR	45, 85	1951–2100
	CSIRO_QCCCE-CSIRO-Mk3–6-0	45, 85	1951–2100
KNMI-RACMO22T	ICHEC-EC-EARTH	45, 85	1950–2100
	ICHEC-EC-EARTH	26	1950–2100
	MOHC-HadGEM2 E S	26, 45, 85	1951–2099
DMI-HIRHAM5	ICHEC-EC-EARTH	45, 85	1951–2100
	NCC-NorESM1 M	45, 85	1951–2100
CLMcom-CCLM4–8-17	CNRM-CERFACS-CNRM-CM5	45, 85	1950–2100
	MOHC-HadGEM2 E S	45, 85	1951–2099
	ICHEC-EC-EARTH	45, 85	1950–2100
	MPI-M-MPI-ESM-LR	45, 85	1950–2100
CCCma-CanRCM4	CCCma-CanESM2	45, 85	1950–2100
BCCR-WRF331C	NCC-NorESM1 M	45, 85	1951–2100
MPI-CSC-REMO2009	ICHEC-EC-EARTH	26,45, 85	1950–2100
	MPI-M-MPI-ESM-LR	26,45, 85	1950–2100
GERICS-REMO2009	IPSL-IPSLCM5A-LR	26,85	1950–2100
	MIROC-MIROC5	26	1950–2100
	MOHC-HadGEM2-ES	26	1950–2099
	NOAA-GFDL-GFDL-ESM2G	26	1950–2100
UQAM-CRCM5	CCCma-CanESM2	45	1951–2100
	MPI-M-MPI-ESM-LR	45	1951–2100
CNRM-ALADIN53	CNRM-CERFACS-CNRM-CM5	45, 85	1951–2100
ICTP-RegCM4-3	MPI-M-MPI-ESM-LR	85	1979–2099

4. Results and discussions

4.1. Projected change in mean temperature and precipitation

The multi-model ensemble mean of the projected changes in precipitation and temperature at annual and seasonal (MAM and JJAS) timescales under 1.5 and 2.0 °C GWLs are shown in figures 2–4 respectively. Figure 2 shows that the RCMs simulations project an increase in annual mean temperature over the entire GHA region. This change increases from 0.5 to 1 °C, moving from the coastal belt of Tanzania towards the interior. The spatial pattern of warming under 2 °C GWL is geographically similar to that of 1.5 °C GWL, however, the magnitude is higher. Particularly noteworthy is the difference between 1.5 and 2 °C GWLs being larger than 0.5 °C over nearly all land points (with values reaching 0.8 °C), showing that GHA will warm faster than the global mean, and that land regions warm more rapidly than ocean regions (Sutton *et al* 2007).

Projected changes in precipitation have a similar spatial pattern but vary in magnitude across the region. There is a wetting signal over Somalia, Kenya, Tanzania, southern Ethiopia, Rwanda and Uganda and a drying signal over the Ethiopian highlands. Over Somalia and northern Tanzania most of the models ($>$ 80%) agree on the sign of the precipitation change; however, as the signal to noise ratio is less than 1, this means that the absolute value of projected change can vary greatly across models.

During the long rains (MAM) the projected change in near surface temperature under 1.5 °C GWL shows an increase ranging between 0.5 and 1.5 °C relative to the control period, with the lowest increase being projected along the coast of Tanzania (figure 3). Under a 2 °C GWL an increase in surface temperature above 1.5 °C is projected over GHA except Tanzania coastal belt. The projected differences between the two warming levels indicates similar patterns as individual warming level with more increase ($>$0.7 °C) projected over the northern part of the domain.

Although the projected precipitation change is usually small and/or uncertain across models for both GWLs (as indicated by the fact that the signal to noise ratio is lower than 1 and less than 80% of runs agree on the sign of change), it is important to note that with an extra 0.5 °C of warming, most of the models agree on projecting drier conditions over the Ethiopian highlands during MAM.

Although the projected surface temperature change for JJAS season has similar spatial patterns to the annual and MAM ones (figures 2 and 3), it is of particular

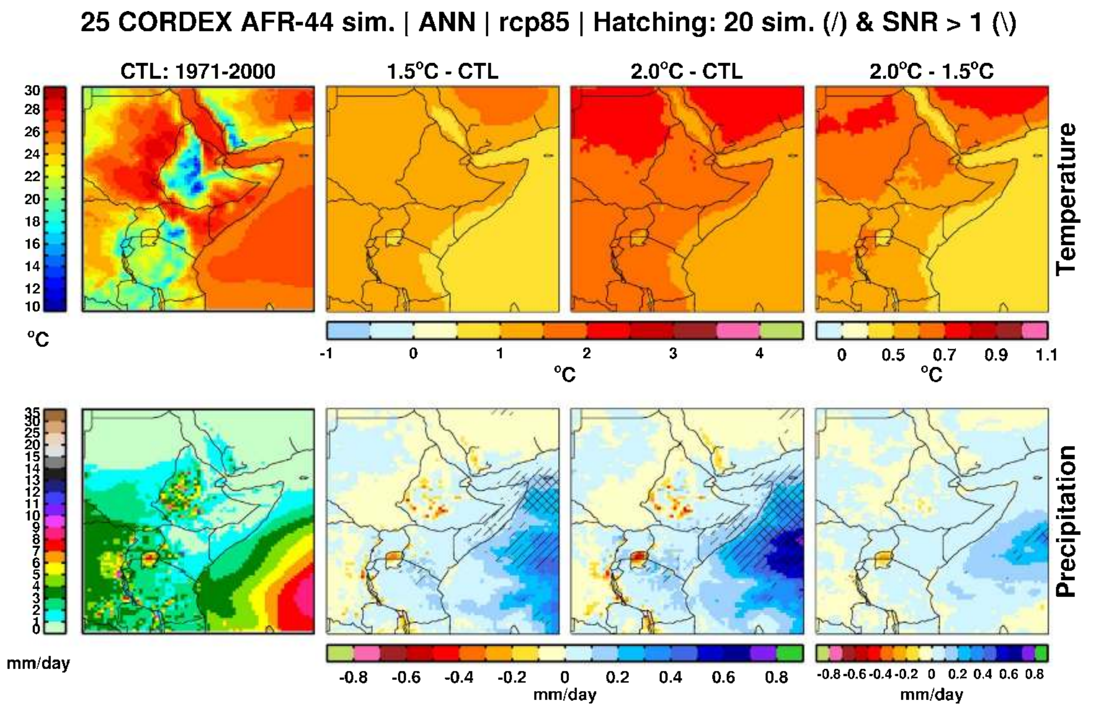

Figure 2. Annual changes in temperature (first row) and rainfall (second row) under 1.5 and 2.0 °C global warming relative to 1971–2000 control period (CTL) based on the ensemble mean of 25 CORDEX RCP8.5 simulations. First column shows annual mean temperature and rainfall for control period (1971–2000). Second and third columns show differences in annual mean temperature and rainfall between future and CTL during 1.5 and 2 °C GWLs, respectively. Fourth column shows differences in annual mean temperature and rainfall between 2 and 1.5 °C. Areas where at least 80% of the simulations (20 of 25) agree on the sign of the change are marked by positively sloped hatch. Areas where the signal to noise ratio is equal or more than 1 are marked by negatively sloped hatching. For temperature all grid boxes satisfy the two criteria (the agreement and signal to noise ratio) and the hatching is not shown.

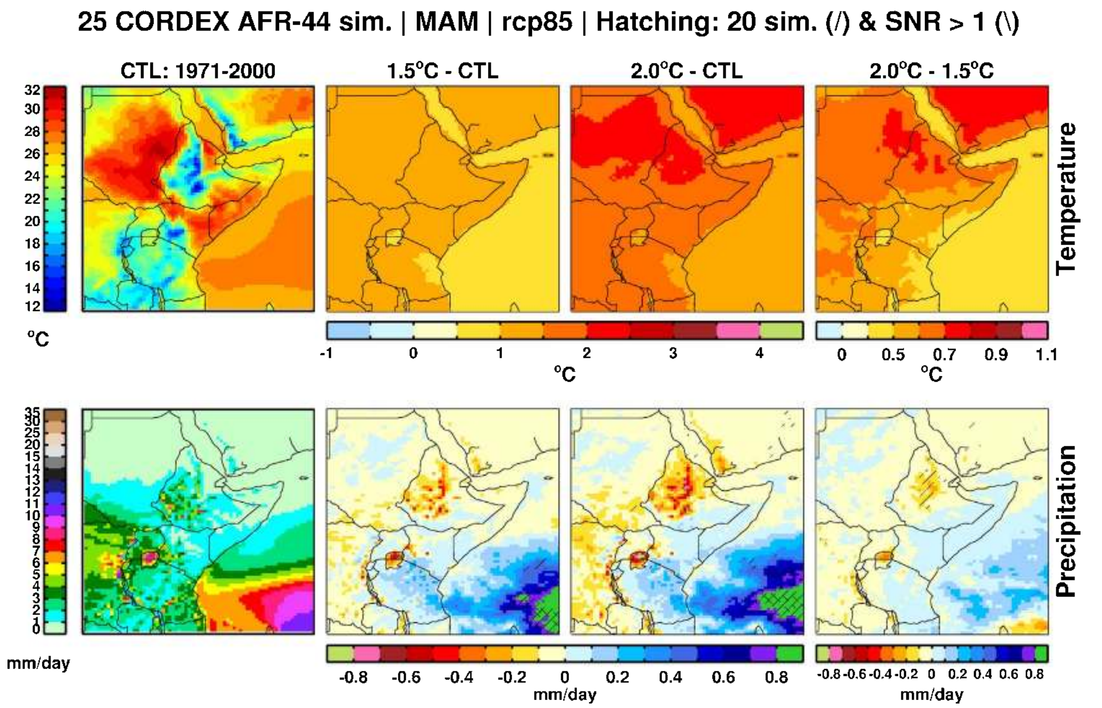

Figure 3. As for figure 2 but for the MAM season.

importance to note that the northern parts of Sudan are almost 1 degree hotter under 2 °C of global warming than under 1.5 °C. Rainfall distribution over GHA during JJAS, shown in figure 4, has different patterns compared to those in figures 2 and 3. This can be related to several factors, including the shift in the position of the Intertropical Convergence Zone (ITCZ) (Nicholson 2016a). Climatologically, northern parts

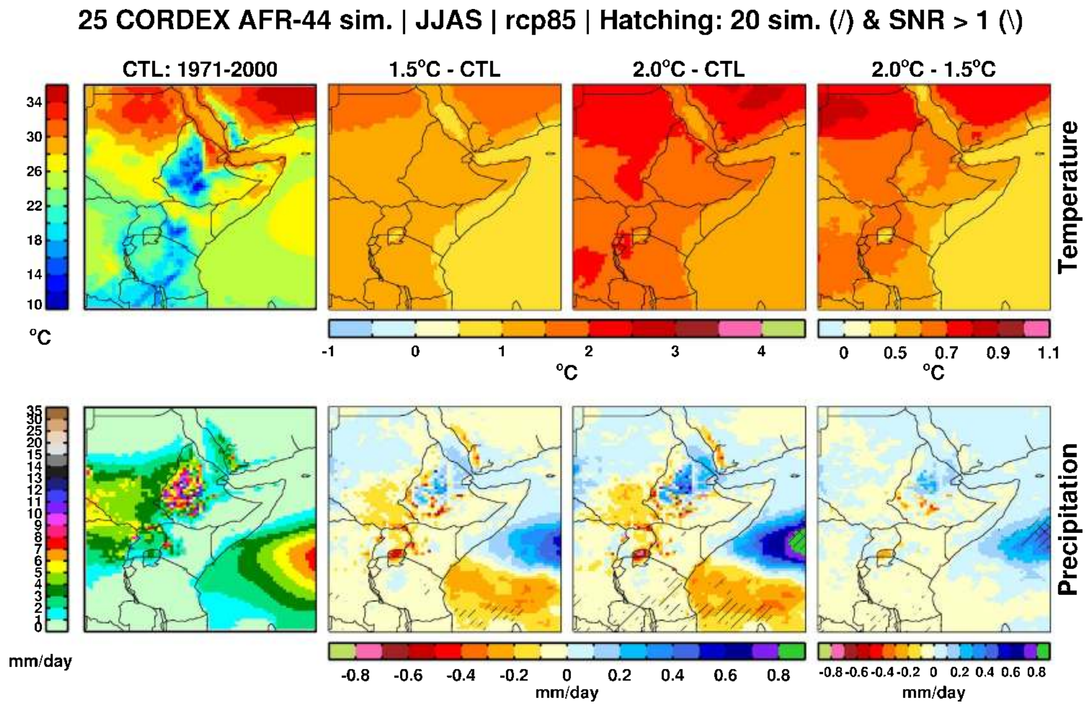

Figure 4. As for figure 3 but for the JJAS season.

of GHA receive rainfall during this season when the relative ITCZ position is in the northern hemisphere. Southern parts of the domain, however, usually experience cool and dry breeze from the intensification of the high pressure systems (Mascarine and St. Helena Highs) during this period of the year. In this case, there is robust drying signal over Tanzania and southern part of Kenya under 2 °C of global warming, suggesting the little rain received over these regions during this season will become even less. The highest increase in rainfall (0.5 mm day^{-1}) is projected over the Ethiopian highlands, while projected decrease of rainfall (∼−0.2 mm day^{-1}) is simulated over Southern Sudan. Over the northern parts of Sudan there is a very weak wetting signal in both scenarios that contrasts the dramatic difference in temperature change. These regional changes could, however, be interpreted with caution because of the influence of local and remote sea surface temperatures (SSTs) on the region; in fact, the simulation by CMIP5 models of coastal SSTs and teleconnections such as ENSO and IOD that influence rainfall in the GHA region still have biases that may influence the results (Kim and Yu 2012, Cai and Cowan 2013, Endris *et al* 2016, Weller and Cai 2013, Taschetto *et al* 2014).

4.2. Projected mean change in consecutive dry and wet days

The projected change in mean annual CDD and CWD relative to the control period is shown in figure 5. Under both GWLs, dry spell duration is projected to increase over most of the region with the possible exception in northern Uganda and north-west Kenya. Robust changes are projected over central and parts of northeastern Tanzania, where both GWLs show more than 20 simulations agreeing on the increase. A comparison between 1.5 and 2 °C shows that the 0.5 °C increase in the temperature will result in longer dry spells over most of the region except over Somalia. On the other hand, CWD are expected to decrease over most of the region, increasing westwards away from the coast: this change becomes robust amongst the simulations at the 2 °C GWL in the central and western parts of the domain.

The MAM season is important for the countries within Equatorial East Africa especially for the sectors that are sensitive to rainfall variability. As such, increased rainfall variability during this season can negatively impact food security and major production sectors within the region. Dry spell duration during MAM is projected to increase by up to three days over the northern and southern parts of the domain under both warming levels (figure 6); however, this season may not be a considerable contributor to the total annual rainfall. The change signal of CWD and CDD changes is not robust and large inter-model variability in the mean change signal still exists, consistent with mean precipitation changes under both GWLs. These results may have implications for agricultural activities especially in arid and semi-arid lands, where evapotranspiration is high and matching of plant phenology with the dry spell lengths is critical (Sivakumar 1992). Changes in CDD and CWD are more pronounced under a GWL of 2 °C than 1.5 °C.

JJAS seasonal rainfall occurs primarily in the northern parts of the domain. The projected rainfall change

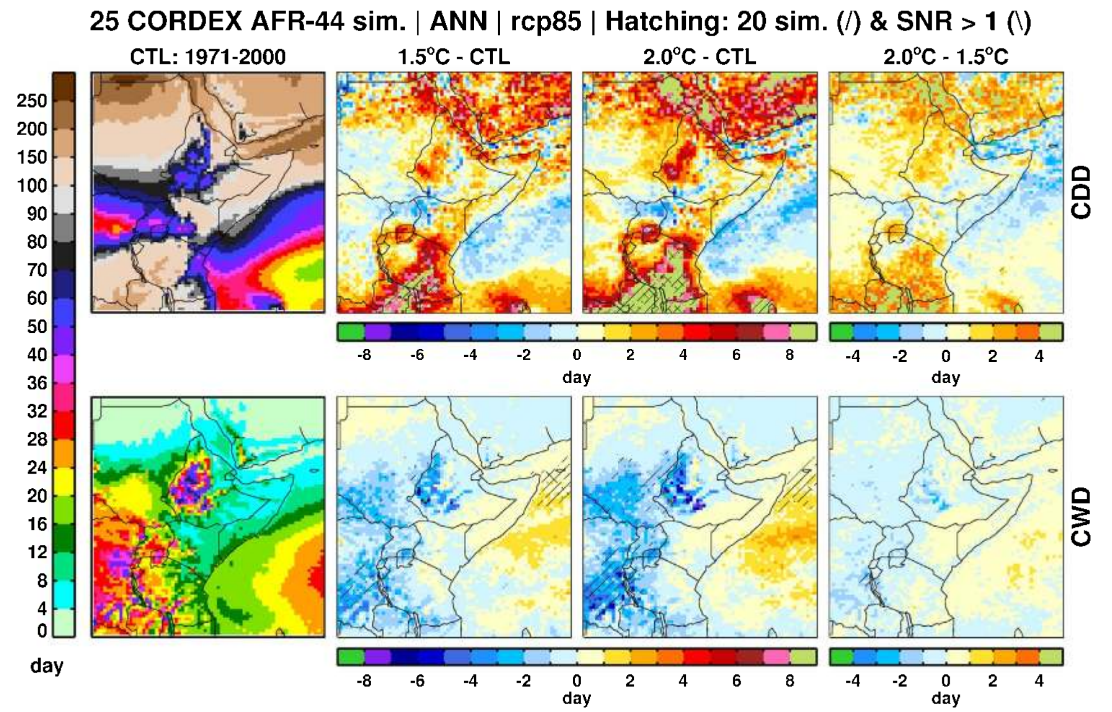

Figure 5. Annual changes in CDD (first row) and CWD (second row) under 1.5 and 2.0 °C global warming relative to 1971–2000 historical period based on the ensemble mean of 25 CORDEX RCP8.5 simulations. First column indicates the number of CCD and CWD for control period (CTL). Second and third columns show projected changes in CDD and CWD between future and present under 1.5 and 2 °C global warming periods, respectively. Fourth column shows differences in CDD and CWD between 2 °C and 1.5 °C areas, where at least 80% of the simulations (20 of 25) agree on the sign of the change are marked by positively sloped hatching. Areas where the signal to noise ratio is equal or more than 1 are marked by negatively sloped hatching.

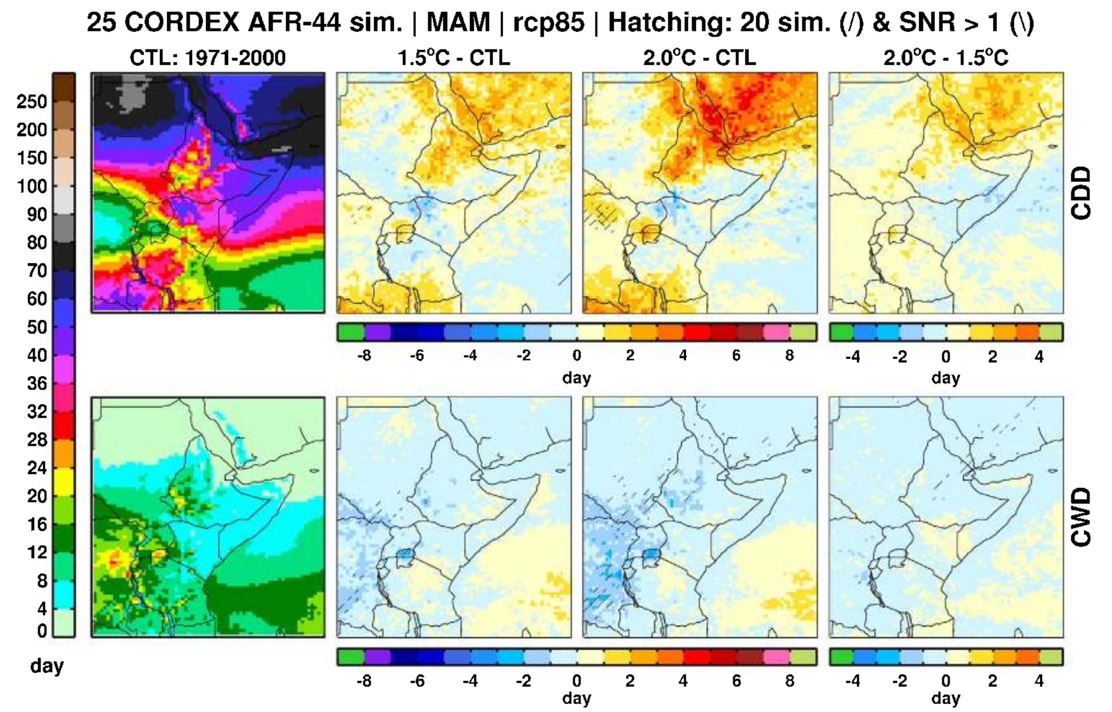

Figure 6. As for figure 5 but for the MAM season.

is heterogeneous over most parts of GHA. The number of CDDs is projected to decrease over Sudan, and northwestern Ethiopia, consistent with the increase in mean precipitation (figure 4). In the Equatorial region, a large increase in the length of dry spells of up to 8 days is projected in areas such as Uganda, South Sudan, Western Kenya and much of the coastal parts of East Africa that receive considerable amounts of

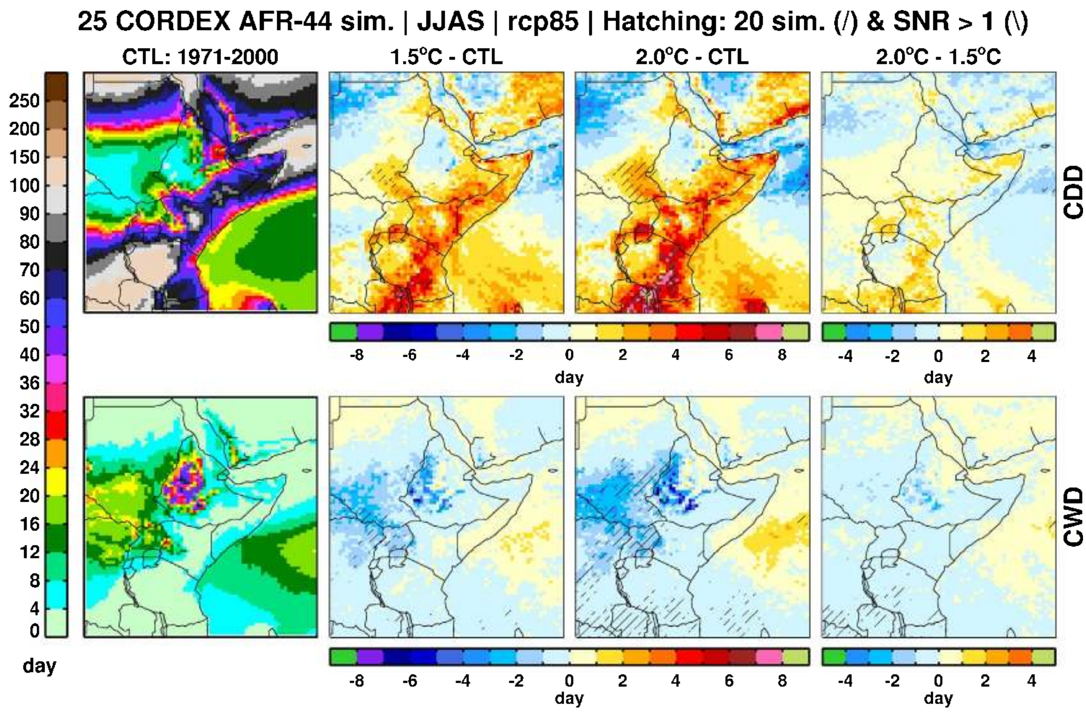

Figure 7. As for figure 6 but for JJAS season.

rainfall during this season (figure 7). This may impact negatively on food security, water availability and health especially for the people living in the dry land regions of the study domain (Huang *et al* 2017). However, there is a large uncertainty in the models results, as less than 80% of the runs agree on the sign of change. On the other hand, there is a good agreement between simulations in projecting a decrease in the number of CWD over much of the study domain especially under the 2 °C warming, although inter-model variability is large. The agreement among models in the changes in CDD and CWD is more conspicuous under 2 °C especially over South Sudan and southern Tanzania. The agreement in the change signal in these areas could provide scientific evidence for formulating actionable policies geared towards adapting to the projected changes under different warming levels in a region dogged by frequent drought (Nicholson 2014).

5. Summary and conclusions

This study analyzed the potential impacts of the mean global temperature increases under global warming limits of 1.5 and 2 °C, above the pre-industrial levels on the changes in mean and extreme precipitation and temperature over the Greater Horn of Africa. The analysis focuses on the annual and seasonal (JJAS and MAM) timescales.

Analysis of the projected changes in mean surface temperature over GHA shows that the region warms faster than the global mean, up to more than 1 °C under the 1.5 °C GWL compared to the control period. Moreover, the effect of global warming under 2 °C level over the region is higher than that of 1.5 °C. This warming will most likely lead to an increase in the length and frequency of heat waves over the region (Russo *et al* 2016, Ceccherini *et al* 2017, Dosio 2017). Although the spatial patterns of projected changes in temperature are similar between seasons, the expected warming extent is greater during JJAS compared MAM and annual timescales.

The magnitude of warming increases from the Tanzanian coastal belt to the interior and northern part of the region, consistent with Sutton *et al* (2007), who demonstrate an amplification of the warming signal relative to the global mean over land compared the ocean. However, we demonstrate this on a regional scale and suggest further investigation to assess how unusual this amplification over the GHA is compared to the global land average amplification (or Africa land or tropical land averages), to help assess the extent to which temperature changes are expected to be particularly problematic for GHA compared to elsewhere.

The projected changes of annual mean rainfall distribution show decrease (increase) over the western (eastern) parts of GHA, and over Somalia, the wetting signal is evident in over 80% of the models, although large uncertainties exist amongst them. Unlike temperature, the projected changes in rainfall patterns are dissimilar between MAM and JJAS seasons. During JJAS rainy season, wetting is projected under both 1.5 °C and 2 °C GWLs in the northern parts of the region and drying over South Sudan, South western part of Ethiopia and northern part of Uganda.

There is a robust drying signal across simulations in the southern parts of the region during JJAS season. During MAM, simulations project increase in precipitation over eastern part of the region, and drying over most part of Ethiopia and western part of the region. It is important to note that the model uncertainty for rainfall change is large compared to the temperature change.

The annual average duration of CDD under both GWLs show a large increase by up to 9 days over the southern and central parts of the region as well as northeastern Tanzania. The annual duration of CWD is projected to decrease over most of the region, except the coastal regions where a small increase is evident. CDD length during MAM season is projected to increase up 5 days under 2 °C GWL over northern part of Ethiopia and southern part of the region but there is no agreement on the change across the ensemble members. The length of CWDs within the MAM season is projected to decrease over much of the study domain with most models agreeing on the decrease over southern parts of South Sudan and along the Sudan-Ethiopia border.

During JJAS, which is the rainy season over much of the northern GHA, the length of dry spells is projected to decrease under both 1.5 and 2 °C but to increase in much of the rest of the region. The simulations project a decrease in wet spell duration over much of the study region, and the decrease will be more pronounced under the 2 °C warming, especially over South Sudan and southern Tanzania, where most of the models agree on the sign of the change.

There is a general decrease in the number of CWDs over most of the region. On the other hand, it is likely that Somalia will experience wetter conditions under 1.5 and 2 °C global warming. This may have a positive effect on the agricultural and developmental sectors in the region. However, further investigation is required to ascertain whether the temperature increases will offset any benefit from increased rainfall. A 2 °C warmer future is projected to lead to a decrease in rainfall over the western and northern part of the domain. The areas around the coastal cities, lake regions and highlands are projected to experience greatest impact of increased CDD and reduced CWD. This change will impact negatively on the arid and semi-arid regions of Kenya, Somalia, Ethiopia and Sudan under the 2 °C GWL. The sectors greatly impacted will be agriculture, water and health amongst others. These results suggest that actionable policies geared towards adaptive strategies to alleviate the impacts of global warming are needed.

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