# Impact of climate change on water in south Sudan

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**ABSTRACT:**

The Republic of South Sudan became a member to the United Nations framework convention on climate change on 17th January, 2014 after attaining its independency from Sudan in 2011 after a 98.8% vote in a referendum for self-determination. As one of the least developed countries, which is vulnerable to climate change impacts, having emerged from a long civil war, the country is being faced with a lot of challenges ranging from effects of war to institutional development and economic prosperity. South Sudan is vulnerable to the effects of climate change and associated socioeconomic losses and damages due to the dependence of its population on climate sensitive natural resources for their livelihoods. Given the frequent droughts experienced in the country, a major priority is to promote the harvesting and retention of water for different uses. The poor quality of water can directly impact the water availability, this paper search the possible implication of climate change for the use and management of water resources in South Sudan. By observation there is changes in river water quality and quantity and climate change is serious increased demands for water and give more pressure on water resource because of the impact and is not only from climate also from non-climatic flooding and drought etc.

The aim of this study paper is to review the impact of climate change on water resources to assist the future of water resource in South Sudan and the outcome of this work will also be important for studies on Nile River. Water quantity and quality in South Sudan have declined in the past two decades. This review paper also shows that the impact of climate change is manifested in the frequency of droughts and shrinking rivers and streams. In a number of previously perennial rivers, water flow has become seasonal among. Lower water flows can lead to siltation. Large quantities of sediment are held along the river course downstream and flash flooding is also impacting negatively on the livelihood of the communities downstream as torrential rainfalls had become unpredictable consequently destroying lives of the masses. Crop yield is also being impacted upon by climate change with high reduction in production raising alarming effects on food insecurity. South Sudan is vulnerable to the impacts of climate change due to its poor infrastructure and a range of developmental challenges resulting from the long civil conflict while 95% of the population depend on climate-sensitive natural resources, particularly rain-fed, subsistence agriculture and total dependence on forests as a source of energy and other environmental goods and services.

Key Words: Climate Change, South Sudan, water quality and quantity availability, water demand, water withdrawal.

## INTRODUCTION

### 1.1 Background

The impact of climate change is crucially important for deciding on a proper course for greenhouse gas emission reduction policies. However, establishing a comprehensive estimate of the impact of climate on human welfare is exceedingly difficult. Water is a linchpin that integrates many sub regions and sectors. Water quantity and quality will be directly affected by climate change. Available water supplies also will be affected by changes in demand from multiple sectors competing for water resources.

Changes in the hydrological cycle will cause changes in ecosystems which will, in turn, affect human health (e.g., by altering the geographic distribution of infectious diseases) and biological diversity.

Increases or decreases in annual runoff could occur over much of the lower latitudes and in mid continental regions of mid and high latitudes. Increases in temperature lead to a rise in evapotranspiration which, unless offset by large increases in precipitation or decreases in plant water use, results in declines in runoff, lake levels, and groundwater recharge and levels. The greatest impact of declines in supply will be in arid and semi-arid regions and in areas with a high ratio of use relative to available renewable supply, as well as in basins with multiple competing uses. Alternatively, regions that experience substantial increases in precipitation are likely to have substantial increases in runoff and river flows.

Science and policy agenda on global concern because global warming are continues to rule the world and the primary concern is the impact of climate change on water resource[1]. The 1997 UN comprehensive assessment of the freshwater resources of the world estimated that approximately a third of the world's population were living in countries deemed to be suffering from water stress, they were withdrawing more than 20% of their available water resources. The assessment went on to estimate that up to two-thirds of the world's population would be living in water stressed countries by 2025[2]. Due to impact of Climate change on water resources there is migration and population change. It is very important for water resources managers to know and prepare to deal with the effects of climate change on the changes of water availability. The better understanding on the relationship between climate change, anthropogenic activities and the water resources availability as well as its withdrawal and use, will allow water resources managers to make more rational decisions on water allocation and management[3].

Virtually all studies into the impact of climate change on water resources have assessed the implications of future climate for the current water management system[4].

South Sudan's water resources are unevenly distributed both spatially across the country, and temporally, since water quantities vary substantially between years depending on periodic major flood and drought events. The Nile River hydrological basin covers most of the country. Water is held in perennial rivers, lakes and wetland areas, in seasonal pools, ponds, rivers, streams and extensive floodplains. Water demand is still low given the country's relatively small population, density and the lack of industrial development, but it is expected to increase rapidly in the future with projected population growth and economic development. In 2007, the Ministry of Water Resources and Irrigation reported that the impact of human activities on the availability and quality of water resources was already evident and a growing concern. There is increased pollution, reduced river flows, declining water tables in urban areas and both surface and ground waters are becoming contaminated (MWRI, 2007)[5].

Water is a naturally circulating resource that is constantly recharged. Therefore, even though the stocks of water in natural and artificial reservoirs are helpful to increase the available water resources for human society, the flow of water should be the main focus in water resources assessments. The climate system puts an upper limit on the circulation rate of available renewable freshwater resources (RFWR). Although current global withdrawals are well below the upper limit, more than two billion people live in highly water-stressed areas because of the uneven distribution of RFWR in time and space[1]. Climate change is expected to accelerate water cycles and thereby increase the available RFWR. This would slow down the increase of people living under water stress; however, changes in seasonal patterns and increasing probability of extreme events may offset this effect. Reducing current vulnerability will be the first step to prepare for such anticipated changes.

There is a need to consider the likely positive and negative impacts of climate change on the natural environment and people across the globe. Deltas are widely recognized as being highly vulnerable to the impacts of climate change particularly sea level rises and river runoff changes[6].

Increases in hydrological variability (larger floods and longer droughts) are likely to result in increased sediment loading and erosion, degraded shorelines, reductions in water quality, reduced water supply for dilution of point-source water pollutants and assimilation of waste heat loads, and reduced stability of aquatic ecosystems.

Both the quality and quantity of water must be considered for the sustainable management of freshwater resources. Globally, water quantity is being stressed by changes in climate, increased demand from growing populations, and an increased need of water for agriculture and industry[7].

Water quality is similarly being stressed from pollutants associated with growing populations, land cover change, and irrigation and industrial effluents[8]. Water quality is fundamentally connected to water quantity by the fact that water of inferior quality effectively reduces the amount of available water for some users (or it can dramatically increase the cost of obtaining available water because of necessary treatment).[9]

## 2.0 MATERIALS AND METHODS.

### 2.1 Study Area

South Sudan is a landlocked country that falls almost entirely (96 per cent) within the Nile River Basin in East-Central Africa[10]. It is bordered in the north by Sudan, by Ethiopia and Kenya in the east, by Uganda and the Democratic Republic of the Congo (DRC) in the south, and in the west by the Central African Republic. South Sudan lies within the tropical zone between latitudes 3.5° and 12° North and longitudes 24° to 36° east. It occupies an area of 658,842 km2[11]. The country is covered by extensive grasslands, wetlands and tropical forests. Its natural assets include significant agricultural, mineral, water, and wildlife, timber and energy resources.

With less than 13 people per square kilometre, population density in the country is one of the lowest in sub-Saharan Africa[12]. Livelihoods in the northern dry areas are dominated by seasonal agriculture, pastoralism, fishing and hunting. Livelihood opportunities vary in the low woodland savannahs in the country's centre[13]. The country is divided into three regions (former historic provinces): Bahr el Ghazal in the northwest, Equatoria in the south and Greater Upper Nile in the northeast. The country initially comprised of ten states but this has now increased to thirty-two.

### 2.2 Data Sources

The study review of the impact of Climate Change on water resource in South Sudan was developed through analysis of secondary source data. These sources include reviewed materials present in the journal, books, national presentations, supplemented by non-peer reviewed literature from a wide range of other sources, including international and non-governmental organizations, and some commercial organizations. These sources were collected through comprehensive and extensive literature search using academic reference databases including Web of Knowledge, Science Direct and Google scholar (including databases such as aquatic science, conference papers index for life, Environment and Aquatic science, GeoRef, International Bibliography of the Social Science, Oceanic Abstracts) were all used to identify relevant literature and articles in the news line from the country. This review involved obtaining data from the past and present studies, and current literature on the impacts of climate change on water resource and hydrology. The study relied on secondary data, and the data were analysed using descriptive methods to obtain logical deduction and sequential presentation of facts from the data obtained that gave a precise picture of the subject matter.

### 2.3 The Environmental implication of Climate Change

#### 2.3.1 Water withdrawals and balances

Water availability in upstream and downstream areas of trans-boundary river basins is an extremely sensitive issue[14]. Because South Sudan is located in the "middle" of the Nile Basin, between the upstream Nile Equatorial Countries (Burundi, Democratic

Republic of Congo, Kenya, Rwanda, Tanzania and Uganda) and the downstream Eastern Nile Countries (Egypt, Ethiopia and Sudan), natural water retention, water withdrawals and development activities in countries upstream of South Sudan affect its water quantity and quality[15]. Lateral water transport flows from positive to negative areas and via floods and groundwater flow. Each individual country and water-use sector in the transboundary Nile Basin monitors water data, such as withdrawals, stocks, wastewater return flows and groundwater-well yields, making it difficult to assess the state of the entire basin's water flows. Earth observation data at the ecosystem scale helps to understand the Nile River Basin's major water flows and fluxes[14].

### 2.3.2 Water quality

Higher water temperatures, increased precipitation intensity, and longer periods of low flows are projected to exacerbate many forms of water pollution, including sediments, nutrients, dissolved organic carbon, pathogens, pesticides, salt and thermal pollution. This will promote algal blooms[16], and increase the bacterial and fungal content[17]. This will, in turn, impact negatively on the ecosystems, human health, and the reliability and operating costs of water systems. The Nile Basin Initiative's 2012 State of the River Nile Basin report noted that over the previous several decades, population growth, agricultural intensification and industrial development throughout the Basin has led to accelerating soil erosion and generally deteriorating water quality. Data on the state of South Sudan's water quality and quantity are lacking, but given that it is more sparsely populated than other Nile Basin countries, it is likely that water quality still corresponds to standards set by the riparian countries and those of the World Health Organization[18]. Water quality problems have intensified through the ages in response to the increased growth and concentration of populations and industrial centres. Polluted water is an important vehicle for the spread of diseases. In developing countries 1.8 million people, mostly children, die every year as a result of water-related diseases[19].

At local levels in South Sudan, however, rising urbanisation is associated with municipal wastewater, sewage and industrial effluents running straight into water sources, since most towns have no wastewater treatment facilities, and lack adequate sanitation and sewage management systems[20].

Storm water and wastewater infrastructure may need to include climate change effects in their design and evaluation to improve performance under changing water availability, water demand, and water-quality conditions. Likewise, the use of contemporary best management practices to control future non-point-source pollution situations may be most effective if system developments are planned in the context of possible future climate conditions[21].

### 2.3.3 Quantity of water

Many of the world's countries already struggle under existing water stress from pressures such as irrigation demands, industrial pollution and water borne sewerage. These pressures will be significantly exacerbated by climate change, which for many regions will result in reduced rainfall and increasing temperatures, further reducing the availability of water for drinking, household use, agriculture and industry. As these competing demands intensify under climate change, effective governance for balancing water demands will become essential, particularly in the face of strong pressures to prioritise industrial uses over other uses such as drinking supplies.

For example, in Africa's large catchment basins of Niger, Lake Chad and Senegal, the total available water has already decreased by 40-60 percent[22], and desertification has been aggravated by lower than average annual rainfall, runoff and soil moisture, especially in Northern, Southern and Western Africa. The consequences for water supply include smaller flows in springs and rivers, and decreasing groundwater levels.

In 2016, South Sudan's Ministry of Environment and Forestry reported that over the past two decades, water flow in a number of previously perennial rivers along the border with the Central African Republic had become seasonal. One of the main ecological

impacts of decreased water flow is river siltation. A large part of the sediment created in the White Nile headwaters becomes confined in the Equatorial Lakes, held in the Sudd marshes or deposited along the river course downstream of the Sudd; thus, over its low-gradient course, the Nile's flow is very sluggish[18]. Other impacts include the congestion of irrigation channels, water-table declines, receding wetland areas and the loss of vegetation due to the lack of water. In turn, the loss of ecosystem goods and services is having adverse effects on the livelihoods of people who depend on wetlands within South Sudan[23].

The single most critical environmental issue related to the pollution of local water supplies is the recurring incidence of gastrointestinal diseases, due mainly to the consumption of contaminated water[20].

Water sources are also subject to the runoff of agrochemical fertilisers and pesticides, which adversely affect water quality. In addition, pollution from the development of the oil industry, particularly in the Unity and Upper Nile States, poses serious threats to wetlands and fisheries[24]. For example, spillage during oil exploration and the overuse of agrochemicals threaten the Sudd wetlands with pollution and eutrophication[20].

## 2.4 THE IMPLICATION OF CLIMATE CHANGE ON HUMAN WELFARE

### 2.4.1 CHANGES IN THE DEMAND FOR WATER

The increase in demand is due largely to an increase of population, increase use of domestic appliances and particularly, an increasing usage of water in large scale oil field and industrial use is predicted to decline. Higher temperatures and longer dry periods are expected to lead to increased water demand for irrigation. This may be partially offset by more efficient use of water by plants due to rising atmospheric carbon dioxide.

Higher temperatures are projected to increase water usage for cooling as water withdrawals by electrical generating stations increases. Climate change can be expected to add to this increasing demand. Accordingly Herrington (1996) conquered with this statement when exploring the potential effect of climate change on demand in southeast of England and concluded that per capita domestic demand would rise by an extra 5% by 2021, over that forecast by the NRA, due to climate change temperature increase of just over 1°C

### 2.4.2 Conflict over water

Changes to accessibility of water have the potential to increase conflict, as the competing demands of private, agricultural, and industrial uses for water put pressure on this precious resources. This may exacerbate conflict in existing water stressed areas competing locally for access to natural springs and rivers, as well as lead to conflicts on a larger international trans-boundary scale. For example, in northern Kenya, the Samburu are having to cope with changing patterns of rainfall and reductions in rainfall amount, which coupled with other pressures on the natural resources are leading to increasing conflict among tribal groups over access to scarce water. whereas in Central Asia, reduced water availability for agriculture has increased tensions among the former Soviet states[21]. The republic of South Sudan is characterised by agro-pastoral communities that depends on rain fed agricultural activities and animal farming thus with the growing concern over the deteriorating condition of water quality and quantity, conflict over water resource accessibility is in the rise as tribal conflict over this shared natural resource is evident.

### 2.4.3 Impact on Traditional Institutions of Authority and Social Harmony

One area in which oil pollution has dealt a death knell to our customs and traditions is the rugged individualism which it has fostered amongst members of our communities which is contrary to our communal lifestyles as this has resulted into the disintegration of customs, traditions and social values, such as respect for our elders.

By the Dinka tradition (a common practices among the tribes in the whole of South Sudan), elders are given the traditional authority to be custodians of the community and its protectors in times of stress and inconvenience such as during environmental incidents.

The traditional system ensures that no single individual has the right to take what belongs to the community for him or herself. However with the current trend of climatic change, a new level of pattern of living and social moral decay is taking toll, as more tribal conflict is looming due insufficient availability of water for pastoral communities leading to cattle wrestling and conflict between cattle herders and agro pastoral communities hence land grabbing in rampant.

### 2.5 WATER QUALITY MANAGEMENT

According to the water resource policy, the ministry of water resource and irrigation of the republic of South Sudan is task with the responsibility to maintain and enhance the quality of river, lake and groundwater for the betterment of the population of the republic of South Sudan. They do this both by regulating activities which discharge effluent into water, and by responding to pollution emergencies. The main areas of concern with respect to climate change are the maintenance of water quality through discharge consents, the management of algal blooms, minimising storm sewer overflows and managing pollution incidents (Arnell et al., 1994) possible changes in public health risks were also identified in the 1996 CCIRG report.

#### 2.5.1 Water security under climate change

In most developing countries, especially African and Asian, there are urgent needs to understand the dynamics of local climate patterns and make predictions to respond to climate variability and change. The economies of most developing countries depend heavily on climate-sensitive sectors such as water, agriculture, fisheries, energy and tourism, climate change therefore poses a serious challenge to social and economic development in developing countries[25]. The shortage of water can be augmented from wastewater utilization after suitable treatment[26]. Recycled water for irrigation requires less treatment than recycled water for domestic purposes and till date no documented case of human health problems has been reported by the use of unconventional water for irrigational purposes since irrigational agriculture is zero to none. Through the natural water cycle the earth has recycled and reused water for millions of years[27]. Water recycling by giving technological support can speed up these natural processes. Usually the recycling of unconventional water may be classified as planned recycling and unplanned recycling of which South Sudan lack water recycling mechanism hence water security is a challenge.

#### 2.5.2 Future water use

There are several factors influencing the growth of future water resource use in the republic of South Sudan given the current trend of climate change patterns.

- Population growth: an increase in population means greater demand for water.
- Population concentration: population, particularly in developing countries, is becoming increasingly concentrated in large cities. This has two implications. First, water use is different in an urban environment than in a rural environment. For example, water will be supplied through a pipe network, so more is used than in rural areas, and water is lost through leakage. Second, the increasing concentration of demand means greater pressure on water resources in specific areas such as Juba town, Wau etc.
- Industrial change: industrial development increases the demand for water, but industrial restructuring may reduce it as it can be seen in larger parts of Europe[28]. As water is seen as more of an economic good, it will be used more efficiently in a country that values the resource given the increasing water stress population.
- Expansion of irrigation: the growth in irrigated areas will lead to more usage of water for agriculture, but this may be offset to a certain extent by improvements in irrigation efficiency by government of respective countries.

- Water use efficiency and demand management: more generally, increased water use efficiency and demand management measures will bring down domestic, municipal and service industry demands, particularly in developing countries.

Environmental requirements: increasing demands for environmental protection will put additional constrains on water resource use. These demands are currently not included in estimates of resource use.

## 3.0 RESULT AND DISCUSSION

Water uses in the Nile Basin as a whole, threaten its capacity to meet the region's future water demand, including the water needs of South Sudan. Throughout the Nile Basin, irrigated agriculture accounts for more than 80 per cent of water withdrawals[10]. Compared to other countries in the Nile Basin, South Sudan's water withdrawal is very low.

According to the Food and Agriculture Organization of the United Nations, total water withdrawal estimates in pre-2011 Sudan was about 27,590 million m³ for the year 2005. The largest water user by far was agriculture, with 26,150 million m³. Municipalities and industry accounted for withdrawals of 1,140 million m³ and 300 million m³, respectively. To arrive at an estimate for water use in South Sudan after 2011, Food and Agriculture Organization calculations were based on the figures for pre-2011 Sudan, with the following assumptions: the same total for South Sudan and Sudan together; no essential changes had taken place; almost all irrigation is located in Sudan; the population of South Sudan is 17 per cent of the total population of pre-2011 Sudan; and most (75 per cent) of the industries are located in Sudan (specifically in the petrol sector)[29]. After 2011, it is estimated that surface and groundwater withdrawal (primary and secondary) is about 658 million $m^3$/year, representing about 1.3 per cent of the total renewable water resource, with agriculture using the most water and a per capita annual withdrawal of about 60 $m^3$ [30]. By comparison, annual per capita water withdrawal in Ethiopia is 106 $m^3$, in Egypt it is 911 $m^3$ and in Sudan, it is 714 $m^3$.

### 3.1 Rural communities, sustainable development and water conflicts

Transboundary water co-operation is recognised as an effective policy and management tool to improve water management across large regions sharing common resources. Climate change and increased water demand in future decades will represent an added challenge to such framework agreements, increasing the potential for conflict at the local level. For instance, unilateral measures for adapting to climate-change-related water shortages can lead to increased competition for water resources. Furthermore, shifts in land productivity may lead to a range of new or modified agricultural systems, necessary to maintain production, including intensification practices. The latter, in turn, can lead to additional environmental pressures, resulting in loss of habitat and reduced biodiversity, siltation, soil erosion and soil degradation[31].

The demand for groundwater resources is likely to increase where surface water resources are becoming inaccessible or unavailable. Intensification of irrigated cropping to meet the food demand of the growing population may also increase groundwater use. Although in South Sudan irrigation practices is very minimal, the need for water resource management is very crucial and estimation of future demand is paramount for the sustainability of population of the republic of South Sudan.

### 3.2 Water Resources Management

There are several water-management options that might be considered to facilitate adaptation to climate change, including operational changes, demand management, and infrastructure changes. Climate change may translate into changed design and operational assumptions for determining resource supplies, system demands, system performance requirements, and operational constraints. The strategy options available for consideration will vary from system to system, as will the preference among these options. The below outlines some of the potential strategies that might be considered and also discusses some of the challenges in evaluating and implementing the adaptation options[21].

The Water Resources Management Strategy of South Sudan aims to improve knowledge and capacity in water resource mapping, assessment and monitoring; strengthen the water information system; and promote conflict prevention and sustainable management of water resources

The national government of different countries particularly in the less developed nation must undertake this key ways for water management policies and institutions to address the impacts of climate changes on water resources;

- Undertake assessments to identify areas prone to shortages under climate change and inform integrated water resources management.
- Promote the development of water harvesting structures, including dykes, water reservoirs and canals, to increase water availability.
- Improve water and sanitation infrastructure in urban areas to improve water supply and quality.
- Develop supplementary irrigation systems in rural areas to improve agricultural production and increase food security.
- Establish a regulatory framework for the monitoring of water quality, including penalties for pollution of water sources.
- Develop a solid waste management plan to ensure water quality is maintained.

Although the government of South Sudan is gradually instituting water management policies and regulations, the state of conflict, low population densities and widely scattered villages and towns present formidable challenges to providing water facilities, services and infrastructure in a cost-effective way.

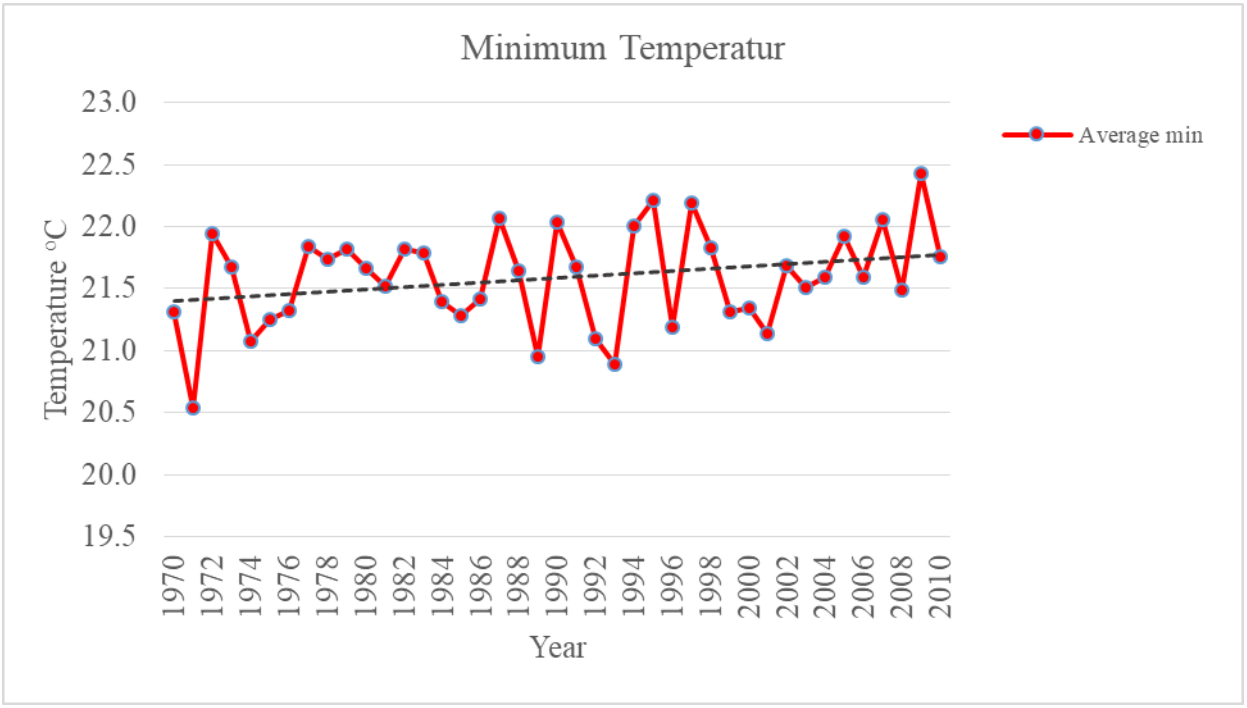
### 3.3 Temperatures are increasing

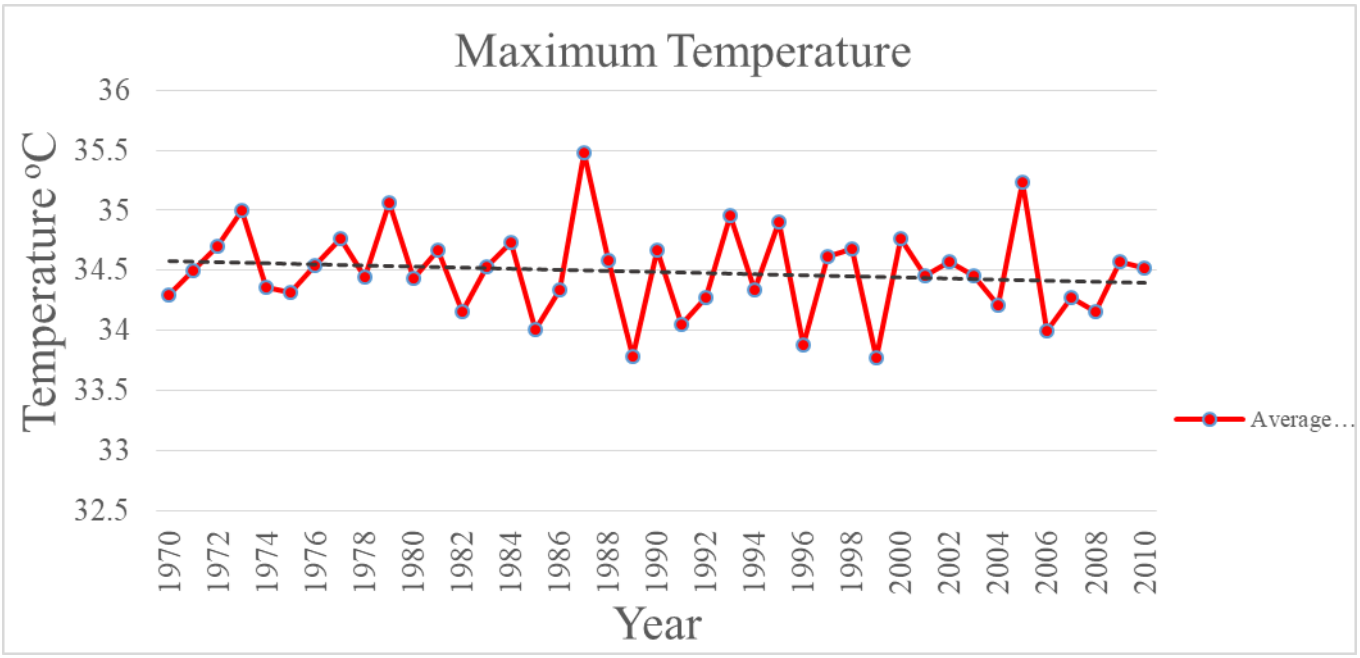
Global average surface air temperature has increased substantially since 1970[32]. The estimated change in the average temperature of Earth's surface is based on measurements from thousands of weather stations, ships, and buoys around the world, as well as from satellites. These measurements are independently compiled, analysed, and processed by different research groups. There are a number of important steps in the data processing.

These include identifying and adjusting for the effects of changes in the instruments used to measure temperature, the measurement times and locations, the local environment around the measuring site, and such factors as satellite orbital drift. For instance, the growth of cities can cause localized "urban heat island" effects.

A number of research groups around the world have produced estimates of global-scale changes in surface temperature. The warming trend that is apparent in all of these temperature records is confirmed by other independent observations, such as the melting of Arctic sea ice, the retreat of mountain glaciers on every continent,[33] reductions in the extent of snow cover, earlier blooming of plants in spring, and increased melting of the Greenland and Antarctic ice sheets.[34],[34b] Because snow and ice reflect the Sun's heat, this melting causes more heat to be absorbed, which causes more melting, resulting in another feedback loop.[35]

Additionally, temperature measurements above the surface have been made by weather balloons since the late 1940s, and from satellites since 1979. These measurements show warming of the troposphere, consistent with the surface warming.[36],[37] They also reveal cooling in the stratosphere.[36] This pattern of tropospheric warming and stratospheric cooling agrees with our understanding of how atmospheric temperature would be expected to change in response to increasing greenhouse gas concentrations and the observed depletion of stratospheric ozone.[38]as it can be seen in the climatic condition in the republic of South Sudan where in the 1970's the temperature cooler than today.



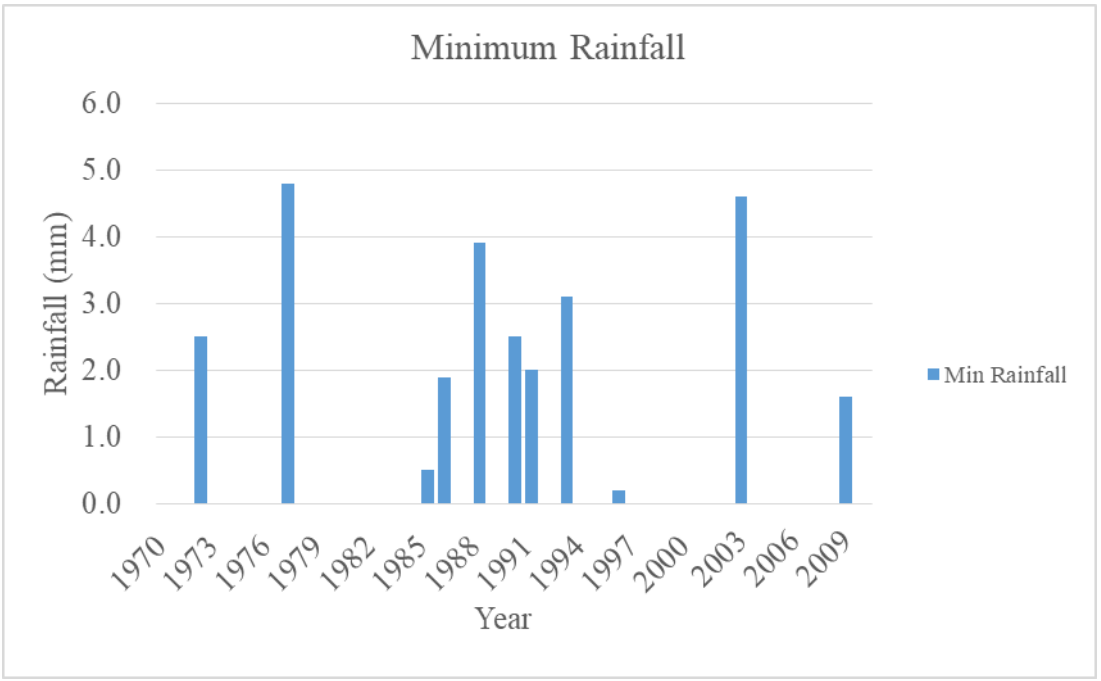



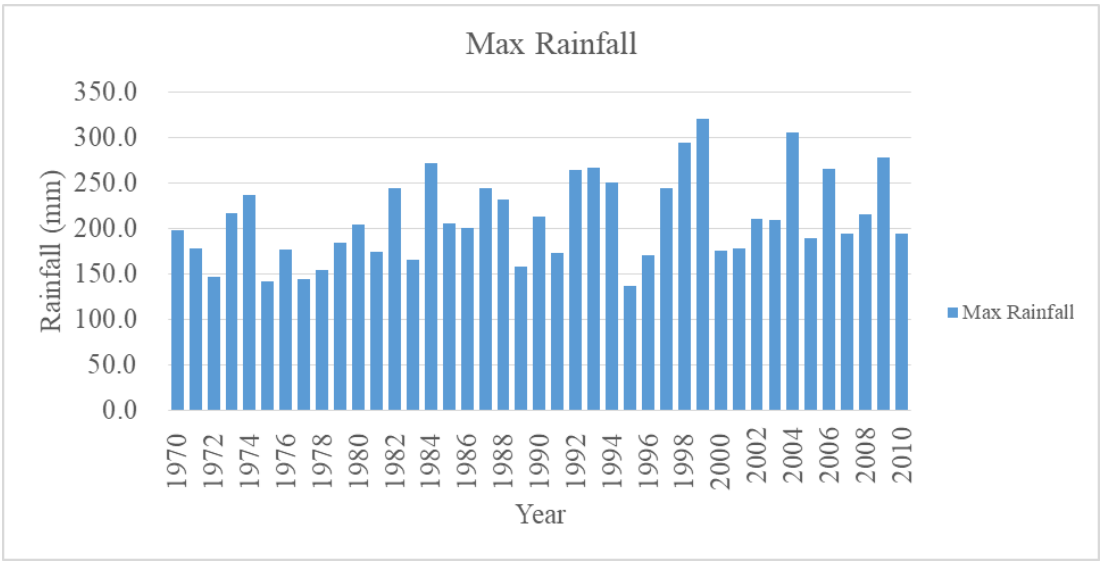

Increased extremes of dryness and wetness are projected for much of the globe, meaning a generally greater risk of droughts and floods. This has already been observed and is projected to continue. In a warmer world, precipitation tends to be concentrated into heavier events, with longer dry periods in between.

### 3.4 Precipitation patterns are changing

Precipitation is not distributed evenly over the globe. Its average distribution is governed primarily by atmospheric circulation patterns, the availability of moisture, and surface terrain effects. The first two of these factors are influenced by temperature. Thus, human-caused changes in temperature are expected to alter precipitation patterns, observations show that such shifts are

occurring compared to 1980's in the republic of South Sudan with the current situation as changes have been observed in the amount, intensity, frequency, and type of precipitation.

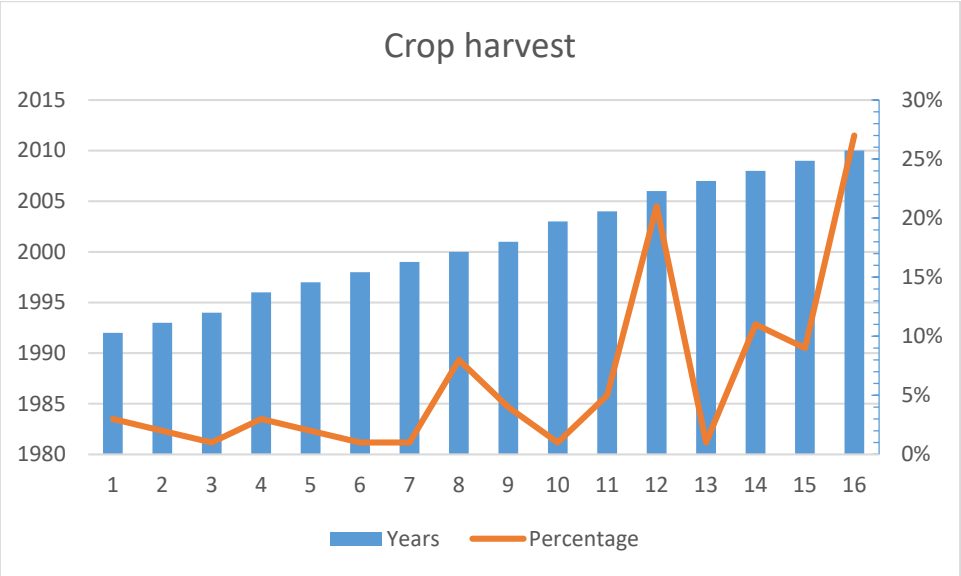



### 3.5 Crop production patterns

According to the Food and Agriculture Organization of the United Nations, total water withdrawal estimates in pre-2011 Sudan was about 27,590 million m³ for the year 2005. The largest water user by far was agriculture, with 26,150 million m³. In the below figure, shows the results of water resource management compared to the early days when mechanised system of agriculture is lacking in the country.

However, in a warmer future climate, there will be an increased risk of more intense, more frequent, and longer-lasting heat waves, example of the type of extreme heat event that is likely to become much more common unless people adapt to new climate change adaptation mechanism.




### 3.6 Factors contributing to current vulnerability to climate variability

#### 3.6.1 Reliance on rain-fed subsistence agriculture

Traditional subsistence agriculture is the dominant economic activity in the republic of South Sudan with approximately 78% of households reliant upon crop farming and animal husbandry as their main sources of livelihood. Farmers rely on rain fed agricultural activity and the use of traditional methods of farming. This combination renders them highly vulnerable to climate variability, particularly erratic rainfall. Unfavourable weather conditions such as persistent droughts and annual flooding resulting into crop and livestock losses. Droughts are also enhancing the encroachment of the desert while flash floods have destroyed forests in low lying areas of South Sudan and particularly in areas close to the Sudd and Marcher wetlands and the White Nile.

#### 3.6.2 Increased soil erosion

Deforestation, overgrazing and wildfires and soil erosion in South Sudan is increasingly becoming a threat to the country. Consequently rivers, lakes, seasonal streams, are silting up, reducing the supply of water for domestic uses. Soil quality is also deteriorating which is negatively affecting agricultural productivity.

#### 3.6.3 Increased deforestation

With the independency of South Sudan, influx of refugees, and population growth in South Sudan have resulted in an increased demand for fuel wood, as well as land for agriculture and residential purposes. The alarming rate of deforestation is accelerating day in day out. Land cover changes indicates a dramatic shift from woodland and forest to cultivated land and bare soil. Deforestation and habitat degradation have decreased the ability of forest ecosystem to provide important environmental goods and services to rural communities. This increases the vulnerability of rural communities to climate variability, as the goods and service provided by these ecosystems buffer communities against the crop failures associated with erratic rainfall, floods and droughts. Deforestation is also having a negative impact on biodiversity and wildlife conservation in South Sudan.

### 3.6.4 Limited institutional capacity to cope with climate variability

There are several institutional capacity constraints in South Sudan that limit the ability of the government to reduce climate change vulnerability. As a new country, many policies and strategies related to environmental management and agriculture are nascent and do not explicitly include climate variability and change. There is inadequate institutional arrangement in the country for effective coordination, planning and implementation of climate change adaptation interventions. Countries like South Sudan which is under developed has limited financial resources to implement programmes geared towards reducing vulnerability to climate change. These institutional capacity constraints limit the integration of climate change adaptation into national policies and development planning processes in South Sudan.

## 4.0 RECOMMENDATION AND CONCLUSION

### 4.1 Recommendation

Projected increases in human demand for water would exacerbate problems associated with the management of water supply and quality. Managing increased water demands will be particularly problematic in regions experiencing increases in variability and declines in runoff. Improved management of water infrastructure, pricing policies, and demand-side management of supply have the potential to mitigate some of the impacts of increasing water demand.

There is a need for the government of the republic of South Sudan to improve the environmental health related infrastructure to reduce the spread of water borne diseases which will be exacerbated by climate change as the quality of water deteriorates impacting negatively on its availability.

South Sudan is home to the largest designated Ramsar site of environmental importance that helps in purifying and buffering the excess water, the Sudd, which is very crucial in regulating the weather patterns in the Sahel region, the horn of Africa and the greater East Africa region. The Sudd wetland as a barrier to the Southward encroachment of the Sahara Desert and its preservation and management should be a top priority of the republic of south Sudan.

### 4.2 Conclusion

Over the next few years, an increasing population and increasing use of water will put increasing pressure on water resources pressures will increase most rapidly in parts of the world. Climate change has the potential to exacerbate water resource stresses in some areas, but ameliorate them in others. This paper describes an Impact of climate change on water resources. The climate change impact on water resources has been shown to be very sensitive to the climate change scenario, to the water demand, quality, quantity scenario, and also to the precise definition of water resource stress.

Water quantity and quality in South Sudan have declined in the past two decades. In a number of previously perennial rivers, water flow has become seasonal. Lower water flows can lead to siltation. Large quantities of sediment are held along the river course downstream. With municipal wastewater, sewage and industrial effluents running straight into water sources due to a lack of wastewater and sanitation management, water quality is declining in urban areas and contaminated water is responsible for recurring incidences of gastrointestinal diseases. Other significant threats to water resources.

## Reference:

1. Vorosmarty, C. J., Global Water Resources: Vulnerability from Climate Change and Population Growth. *Science* **2000,** *289* (5477), 284-288.
2. Arnell, N. W., Climate change and global water resources: SRES emissions and socio-economic scenarios. *Global Environmental Change* **2004,** *14* (1), 31-52.

3. Xu, Z. X.; Chen, Y. N.; Li, J. Y., Impact of Climate Change on Water Resources in the Tarim River Basin. *Water Resources Management* **2004,** *18* (5), 439-458.
4. Kaczmarek, Z., 'WaterResources Management', inWatson,R.T.,Zinyowera, M. C.,andMoss, R. H. (eds.), Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change. Scientific-Technical Analyses. Contribution of Working Group II to the Intergovernmental Panel on Climate Change Second Assessment Report, Cambridge University Press, Cambridge,. **1996**, pp. 469–486. .
5. MWRI, Water Policy. Juba: Ministry of Water Resources and Irrigation (MWRI), Government of South Sudan. Retrieved November 14, 2016. **2007**.
6. Nicholls, R. J., Hutton, C.W., Lazar, A.N, Allan, A., Ader, W.N., Adams, H., Wolf, J., Rahman, M., Salehin, M.,, integrated assessment of social and environmental sustainbility dynamics in the ganges. **2016**.
7. Wada, Y. a. M. F. P. B., Sustainability of Global Water Use: Past Reconstruction and Future Projections. Environmental Research Letters 9:104003, https://doi.org/10.1088/. **2014**, 1748-9326/9/10/104003.
8. (a) Kundzewicz, Z. W., L.J. Mata, N.W. Arnell, P. D€oll, B. Jimenez, K. Miller, T. Oki, Z. S en, and I., Shiklomanov, 2008. The Implication of Projected Climate Change for Freshwater Resources and their Management. https://doi.org/10.1623/hysj.53.1.3. *Hydrological Sciences Journal*, 53:3-10,; (b) Teixeira, Z., H. Teixeira, and J.C. Marques, , Systematic Processes of Land Use/Land Cover Change to Identify Relevant Driving Forces: Implications on Water Quality. Science of the Total Environment 470–471:1320-1335, https://doi.org/10.1016/j. scitotenv. . **2014.**, .2013.10.098.
9. Borrok, D. M.; Chen, J.; Eldardiry, H.; Habib, E., A Framework for Incorporating the Impact of Water Quality on Water Supply Stress: An Example from Louisiana, USA. *JAWRA Journal of the American Water Resources Association* **2018,** *54* (1), 134-147.
10. NBI, Nile Water Basin Resources Atlas. Entebbe, Uganda: Nile Basin Initiative (NBI). Retrieved July 27, 2017, from http:// nileis.nilebasin.org/content/nile-basin-water-resources-atlas. **2016**.
11. RSS.. Agriculture Sector Framework. Juba: Republic of South Sudan. **2012**.
12. BRACED., Building Resilience to Climate Extremes and Disasters in South Sudan: An anthropological study exploring the perceptions of climate change, adaptation and resilience among agro-pastoral and agriculturalist communities in the Greater Bahr el Ghazal Region. . **2016**.
13. MOE., Fifth National Report to the Convention on Biological Diversity. Juba: Ministry of Environment (MOE), Republic of South Sudan. Retrieved November 09, 2016, from https://www. cbd.int/doc/world/ss/ss-nr-05-en.pdf. **2015**.
14. Bastiaanssen, W., Karimi, P., Rebelo, L.-M., Duan, Z., Senay, G., Muthuwatte, L., & et al. (6), Earth Observation Based Assessment of the Water Production and Water Consumption of Nile Basin Agro-Ecosystems. Remote Sensing, 6(11), 1030610334. doi:10.3390/rs61110306. **2014**.
15. Fernando, N., & Garvey, W. , . Republic of South Sudan - The Rapid Water Sector Needs Assessment and a Way Forward. World Bank. Retrieved November 20, 2016, from http:// documents.worldbank.org/curated/en/434701468302991568/ pdf/799230v10ESW0P0Box0379795B00PUBLIC0.pdf. **2013**.
16. (a) Kumagai, M., K. Ishikawa and J. Chunmeng,, Dynamics and biogeochemical significance of the physical environment in Lake Biwa. Lakes Reserv. Res. Manage.,. **2003**, 7, 345-348; (b) Hall, G., R. D'Souza and M. Kirk, , Foodborne disease in the new millennium: out of the frying pan and into the fire? Med. J. Australia,. **2002:** , 177, 614-618. .
17. Environment Canada, Threats to sources of drinking water and aquatic ecosystems health in Canada. National Water Research Report No.1. National Water Resources Research Institute, Burlington, Ontario, . **2001**, 72 pp. EPIQ (Environmental Policy a.
18. NBI, State of the River Nile Basin. Entebbe, Uganda: Nile Basin Initiative (NBI). Retrieved July 27, 2017, from http://sob. nilebasin.org/. **2012.**
19. WHo, www.who.int/water_sanitation-health/publications/facts2004/en/index.html. **2004**.
20. MOE, The National Environment Protection and Sustainable Development Policy, 2014-2024 Por. Juba: Ministry of Environment (MOE), Republic of South Sudan. Retrieved November 13, 2016. **2014.**
21. By Levi D. Brekke, J. E. K., J. Rolf Olsen, Roger S. Pulwarty, David A. Raff, D. Phil Turnipseed, Robert S. Webb, and Kathleen D. White, <Climate Change and Water Resources Management.pdf>. *science for changing world* **2009**.
22. ERM for WaterAid. Lead consultant: Courtenay Cabot Venton, E. R. M., <climate change and water resources.pdf>. **2005**.
23. MOE, Republic of South Sudan's National Adaptation Programme of Actions (NAPA) to climate change. Juba: Ministry of Environment (MOE), Republic of South Sudan. Retrieved July 27, 2017, from https://unfccc.int/files/adaptation/ workstreams/national_adaptation_programmes_of_action/ application/pdf/south_sudan_final_napa_-_24th_nov-2016.pdf. **2016**.
24. MOE, Republic of South Sudan's National Adaptation Programme of Actions (NAPA) to climate change. Juba: Ministry of Environment (MOE), Republic of South Sudan. Retrieved July 27, 2017, from https://unfccc.int/files/adaptation/workstreams/national_adaptation_programmes_of_action/ application/pdf/south_sudan_final_napa_-_24th_nov-2016.pdf. **2016**.
25. Munang R, J. N., Zhenhan., using data digitalization to inform climate change adaptation policy: informing the future using the present: weather and climate extremes. **2013**.
26. FAO, wastwater treatment and use in agriculture. **2012**.
27. Misra, A. K., Climate change and challenges of water and food security. *International Journal of Sustainable Built Environment* **2014,** *3* (1), 153-165.
28. Department of Geography, U. o. S., Southampton <Climate change and global water resources.pdf>. *Global Environmental Change* **1999**.
29. FAO., South Sudan. Rome: Food and Agriculture Organization of the United Nations (FAO). Retrieved July 27, 2017, from http://www.fao.org/nr/water/aquastat/data/wrs/ readPdf.html?f=SSD-WRS_eng.pdf. **(2016b).** .
30. FAO, South Sudan. Rome: Food and Agriculture Organization of the United Nations (FAO). Retrieved July 27, 2017, from http://www.fao.org/nr/water/aquastat/data/wrs/ readPdf.html?f=SSD-WRS_eng.pdf. **2016b**.
31. MWRI., Water, Sanitation & Hygiene (WASH) Sector Strategic Framework. Juba: Ministry of Water Resources & Irrigation (MWRI), Republic of South Sudan (RSS). Retrieved December 4, 2016, from https://www.unicef.org/southsudan/WASH_ Sector_Strategic_Framework_2011.pdf. **(2011).**
32. The spatial average of annual-average surface air temperatures around the globe is commonly referred to as the global average surface air temperature. .
33. Meier, M. F., M.B. Dyurgerov, U.K. Rick, S. O'Neel, W.T. Pfeffer, R.S. Anderson, S.P. Anderson, and A.F. Glazovsky, Glaciers dominate eustatic sea-level rise in the 21st century. *Science,* **, 2007:** , 317(5841), 1064-1067.

34. (a) Trenberth, K. E., P.D. Jones, P. Ambenje, R. Bojariu, D. Easterling, A. Klein Tank, D. Parker, F. Rahimzadeh, J.A. Renwick, M. ; Rusticucci, B. S., and P. Zhai, [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (eds.)]. , Observations: surface and atmospheric climate change. In: Climate Change 2007: The Physical Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. *Cambridge University Press, Cambridge, UK, and New York,* **2007:**, pp. 235-335; (b) Steffen, K., P.U. 35. Clark, J.G. Cogley, D. Holland, S. Marshall, E. Rignot, and R. Thomas,, Rapid changes in glaciers and ice sheets and their impacts on sea level. In: Abrupt Climate Change. . **2008:**.

36. Jansen, E., J. Overpeck, K.R. Briffa, J.-C. Duplessy, F. Joos, V. ; Masson-Delmotte, D. O., B. Otto-Bliesner, W.R. Peltier, S. Rahmstorf, R. Ramesh, D. Raynaud, D. Rind, O. Solomina, R. Villalba and D. Zhang, Palaeoclimate. [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (eds.)]. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change *Cambridge University Press, Cambridge, UK, and New York,* **2007:**, pp. 433-497.
37. Lanzante, J. R., T.C. Peterson, F.J. Wentz, and K.Y. Vinnikov, [Karl, T.R., S.J. Hassol, C.D. Miller, and W.L. Murray (eds.)]. , What do observations indicate about the change of temperatures in the atmosphere and at the surface since the advent of measuring temperatures vertically? In: Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences. *Synthesis and Assessment Product 1.1 U.S. Climate Change Science Program, Washington, DC,* **2006:**, pp. 47-70.
38. Santer, B. D., P.W. Thorne, L. Haimberger, K.E. Taylor, T.M.L. ; Wigley, J. R. L., S. Solomon, M. Free, P.J. Gleckler, P.D. Jones, T.R. Karl, S.A. Klein, C. Mears, D. Nychka, G.A. Schmidt, S.C. Sherwood, and F.J. Wentz, , Consistency of modelled and observed temperature trends in the tropical troposphere. . *International Journal of Climatology*, **2008:**, 28(13), 1703-1722. .

39. Santer, B. D., J.E. Penner, and P.W. Thorne, [Karl, T.R., S.J. Hassol, C.D. Miller, and W.L. Murray (eds.)]. , How well can the observed vertical temperature changes be reconciled with our understanding of the causes of these changes? In: Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences *Synthesis and Assessment Product 1.1 U.S. Climate Change Science Program, Washington, DC,* **2006:**, pp. 89-118.

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