Southern African Climate

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Abstract

The climate of southern Africa has many contributing factors. There exists a cold ocean current to the west and a warm ocean current to the east causing great variability from west to east. The region extends from the southern tropics to the southern mid-latitudes giving it a range of dominant atmospheric flow. This causes many different climate types to arise anywhere from tropical in the north and along the east coast, arid conditions in the west and temperate in the central and southern regions. Maize grows well during the Austral summer do to adequate rainfall. This is important since the economy depends greatly on the agriculture of the region. The economy relies heavily on agriculture, even though it constitutes only about five percent of the region's economy. Agriculture related business is roughly twenty-five percent of the economy in these countries.

1. Introduction

Southern Africa has many unique features that dictate the climate. It extends from the tropical region in the north to the mid-latitude region in the south. It is surrounded by ocean on the west, south and east. The Agulhas warm current is off the east coast and the Benguela cold current off the west coast. All of this, coupled with a mountainous region in the southeast makes for a wide range of different average temperatures and rainfall. The following sections detail the climate classifications, general circulations in the ocean and atmosphere, agriculture and economy of southern Africa.

2. Köppen-Geiger Classification

The Köppen-Geiger classification system dates back to 1900. It was derived to compare climates from different areas around the world. The Köppen classification system is still the most widely used classification tool in use. Due to this fact, it is logical to start any discussion about climate at this point. Southern Africa has climates ranging from tropical to arid to temperate (Peel et. al., 2007). *Table 1* shows the breakdown of the classification system used, and the temperature and precipitation guidelines accompanying it (Peel et. al., 2007, Table 1). The following is shown in *Figure 1*.

Along the east coast of Mozambique there is tropical savannah. This area does not extend much off of the coast (Peel et. al., 2007, Figure 4). The warmer temperatures arise from the warm Agulhas Ocean current in the western Indian Ocean. This creates a warm sea breeze which allows for warmer temperatures in lower latitudes (Jury et. al., 1993). There is also a small pocket of tropical savannah over extreme eastern Angola and western Zambia (Peel et. al., 2007, Figure 4).

Namibia, Botswana, and parts of Angola, South Africa, Zimbabwe and Mozambique have an arid climate. This arid area is partly caused by a rain shadow formed by the mountains on the east coast. As the warm moist air coming off of the Indian Ocean hits the mountains it rises, and the water vapor condenses and precipitates out. As the air descends on the other side of the mountains it warms and dries causing the rain shadow. The arid is divided into a steppe with hot temperatures and a hot desert. The southwest coast of Angola, northern Namibia, most of Botswana, extreme northern South Africa, extreme southern Zimbabwe, and southern Mozambique is a hot desert. The northwestern coast of Angola and areas east of the desert in northern Namibia, most of Botswana, extreme northern South Africa, and extreme southern Zimbabwe have a hot steppe climate. Western South Africa is a cold steppe (Peel et. al., 2007, Figure 4). There is a small pocket of hot steppe with an area of hot desert inside it in southern Mozambique. This may be caused by the Agulhas Current. When the continental shelf is short, the current is closer to the shore. This causes mesoscale subsidence over the land. When the shelf is longer the current is farther from shore and the subsidence is pulled offshore allowing for convection on land. The current goes between Africa and Madagascar here and is closer to the shore causing less rain to fall (Jury et. al., 1993).

The north and east, not including the coast, are generally a temperate climate with a dry winter and a hot summer. This covers most of Angola, southern Democratic Republic of Congo, Zambia, Malawi, western Mozambique, Zimbabwe and eastern South Africa. There are small pockets of temperate with a dry winter and warm summer over south Angola, south Democratic Republic of Congo, eastern Malawi and western Mozambique, central Zimbabwe and eastern South Africa. Along the coast of South Africa there is a region of temperate with no dry season. The southeast coast has a hot summer and the southern coast has a warm summer (Peel et. al., 1993, Figure 4).

It has been claimed that temperatures in southern Africa have been increasing due to climate change. During the period of 1940-1989, average daily maximum temperatures in South Africa were shown to decrease slightly while minimum temperatures increased. The increase in minimum temperatures was greater than the decrease in maximum temperatures. The weather stations where these measurements were taken from have seen a change in the landscape around them. Most of the stations are in urban areas and development in these areas has taken off in the last three decades. It appears that the urbanization of the region has caused the apparent increase in temperature, since the nineteen non-urban stations in South Africa have shown no significant warming over this period (Hughes and Balling, 1996). It should be made clear that this data is 15 years old, and doesn't necessarily agree with what is going on at present.

3. Circulations

Longwaves in the atmosphere propagate in a clockwise direction in the Southern Hemisphere. Within these longwaves are shortwaves called ridges and troughs. These are responsible for the weather and thus, the climate of southern Africa. The dominant features of circulation in the region are the semi-permanent subtropical anticyclones over the Atlantic Ocean to the west and the Indian Ocean to the east, and a low circumpolar vortex between them over southern Africa (Kelbe 1988). The anticyclones are caused by high

pressure over the oceans and the low circumpolar vortex is caused by low pressure over the landmass. Precipitation in the region is sensitive to sea surface temperature (SST) anomalies, especially during Austral summer (Cook et. al., 2006). The main rainfall season for the region is Austral summer (Reason, 1999).

There is also a Walker-style circulation that affects rainfall variability over the region. Under normal circumstances, this circulation is such that there is convergence near the surface over South America, divergence over the South Atlantic Ocean, and finally, convergence over southeastern Africa. This convergence over Africa creates a low pressure in the area, bringing precipitation (Williams, 2008). Cold anomalies in SST in the South Atlantic Ocean cause this Walker circulation to shift westward by increasing the temperature gradient there. This increases rainfall over southwestern Africa and also increases the number in extreme events (Williams, 2008). *Figure 2* shows the structure of the Walker circulation under normal conditions (a) and during cold SST anomalies (b).

The Indian Ocean also plays a role in the position of the Walker circulation. The Agulhas Current retroflection is just southeast of southern Africa. This is where the current moves away from the continental shelf and turns back on itself. The warmer water of the current, combined with the convergence from the Walker circulation, work to form a tropical-temperate trough (TTT). The TTT is an elongated low pressure area usually over southeastern Africa where storms form (Reason, 1999) and (Williams, 2008). Warmer SST near the Agulhas retroflection cause increased precipitation in southern Africa due to increased convergence of moisture from the Indian Ocean and Atlantic Ocean (Reason, 1999).

4. Agriculture

More than half of the population in southern Africa lives in rural areas. The main crop is maize, and it accounts for about seventy percent of the total human caloric intake (Martin et. al., 2000). Maize is also used in other agricultural products. The growing season is in from December to February during the rainy season which is critical to the food supply of southern Africa. In southern Africa people do not have enough water to irrigate crops; almost all are fed by rain. As the climate changes in southern Africa there is a negative effect on the agriculture. Rainfall has decreased as much as forty percent in some parts and temperature has increased up to six degrees Celsius, causing prolonged drought conditions (Palitza 2009). The limited rainfall and increased temperature in some regions in southern Africa contributes to sharp reductions in crop yields.

El Niño has an effect on rain amounts. An El Niño brings westerly wind to the eastern highlands and increases evaporation. This causes warm and dry conditions during the austral summer. Major El Niño events occurred in 1964, 1973, 1983, 1992, and 1998 (Jury 2002). During that time rainfall over southern Africa was about sixty percent of normal, temperatures increased by five degrees Celsius and evaporative losses were more than 10 mm day^{-1} (Jury 2002). Total land used for crop production shrinks by thirty percent during an El Niño.

5. Economy

The climate of southern Africa has a large influence on the GDP of the area. Agriculture is the main factor for the economy of the region. Dry-land crops

contribute around one billion U.S. dollars every year, but conditions during an El Niño cause that to decline by thirty percent (Jury 2002). Agriculture itself accounts for only about five percent of economic activity; however its indirect influence is estimated to be about twenty-five percent, due to manufacturing and service support needed for commercial farming operations. It is also about thirty-six percent of the regions exports. The GDP in dry periods is about eighty-three percent of what it is in wet periods. Limitations of water cause quotas in domestic and industrial areas leading to production losses. During the drought in 1992 about seventy-percent of the rural population requested relief. Sixty million U.S. dollars were lost in foreign exchange in Zimbabwe alone (Jury, 2001).

6. Conclusion

The climate of southern Africa is diverse. One can almost take a complete world tour of climates just by stopping in this small sector of the globe. The combination of a cold ocean current on the west coast, and a warm current on the east coast, make for a spread of both precipitation amounts and temperatures. This contributes to the importance of the agriculture since any variations in these currents effects the atmospheric circulations and precipitation over the region. Since agriculture plays a vital role in the economies of southern Africa, any change in the climate will have a drastic change on the livelihood of the people who inhabit the area.

7. Appendix

1st	2nd	3rd	Description	Criteria*
A			Tropical	$T_{cold} \geq 18$
	f		- Rainforest	$P_{dry} \geq 60$
	m		- Monsoon	Not (Af) & $P_{dry} \geq 100 - MAP/25$
	w		- Savannah	Not (Af) & $P_{dry} < 100 - MAP/25$
B			Arid	$MAP < 10 \times P_{threshold}$
	W		- Desert	$MAP < 5 \times P_{threshold}$
	S		- Steppe	$MAP \geq 5 \times P_{threshold}$
		h	- Hot	$MAT \geq 18$
		k	- Cold	$MAT < 18$
C			Temperate	$T_{hot} > 10$ & $0 < T_{cold} < 18$
	s		- Dry Summer	$P_{sdry} < 40$ & $P_{sdry} < P_{wwet}/3$
	w		- Dry Winter	$P_{wdry} < P_{swet}/10$
	f		- Without dry season	Not (Cs) or (Cw)
		a	- Hot Summer	$T_{hot} \geq 22$
		b	- Warm Summer	Not (a) & $T_{mon10} \geq 4$
		c	- Cold Summer	Not (a or b) & $1 \leq T_{mon10} < 4$
D			Cold	$T_{hot} > 10$ & $T_{cold} \leq 0$
	s		- Dry Summer	$P_{sdry} < 40$ & $P_{sdry} < P_{wwet}/3$
	w		- Dry Winter	$P_{wdry} < P_{swet}/10$
	f		- Without dry season	Not (Ds) or (Dw)
		a	- Hot Summer	$T_{hot} \geq 22$
		b	- Warm Summer	Not (a) & $T_{mon10} \geq 4$
		c	- Cold Summer	Not (a, b or d)
		d	- Very Cold Winter	Not (a or b) & $T_{cold} < -38$
E			Polar	$T_{hot} < 10$
	T		- Tundra	$T_{hot} > 0$
	F		- Frost	$T_{hot} \leq 0$

*MAP = mean annual precipitation, MAT = mean annual temperature, T_{hot} = temperature of the hottest month, T_{cold} = temperature of the coldest month, T_{mon10} = number of months where the temperature is above 10, P_{dry} = precipitation of the driest month, P_{sdry} = precipitation of the driest month in summer, P_{wdry} = precipitation of the driest month in winter, P_{swet} = precipitation of the wettest month in summer, P_{wwet} = precipitation of the wettest month in winter, $P_{threshold}$ = varies according to the following rules (if 70% of MAP occurs in winter then $P_{threshold}$ = 2 x MAT, if 70% of MAP occurs in summer then $P_{threshold}$ = 2 x MAT + 28, otherwise $P_{threshold}$ = 2 x MAT + 14). Summer (winter) is defined as the warmer (cooler) six month period of ONDJFM and AMJJAS.

***Table 1*. Breakdown of the Köppen-Geiger classification system**

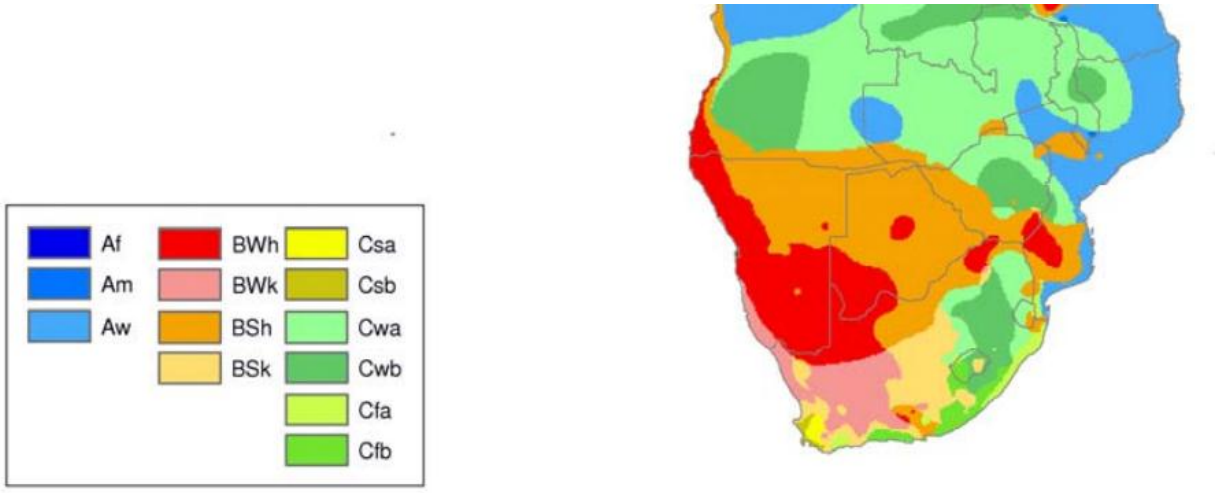

***Figure 1*. Map of Köppen-Geiger classifications for southern Africa**

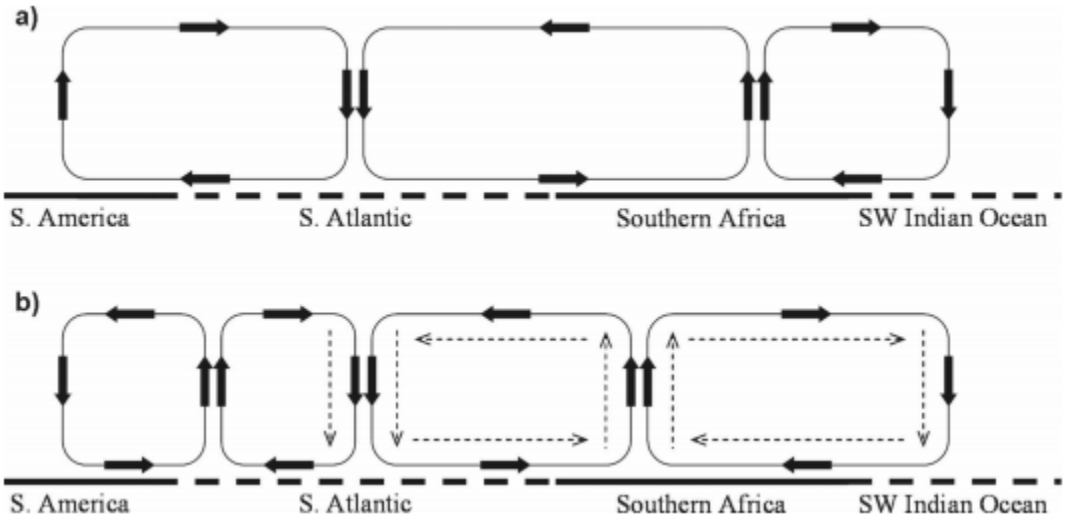

***Figure 2*. Walker-Style circulation over southern Africa during normal conditions (a), and during cold South Atlantic SST anomalies**

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