

## Indigenous Climate Information and Modern Meteorological Records in Sinazongwe District, Southern Province, Zambia

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### Abstract

In 2007, we conducted field research in Sinazongwe District in Southern Province, Zambia, focusing on collecting indigenous information concerning the local climate, which was often embodied in proverbs involving weather forecasts. The indigenous information was compared with recently collected meteorological records and a relationship between popular folk knowledge, local climate, and global climate factors such as ENSO (El Niño and the Southern Oscillation) was suggested. Proverbs related to agriculture and climate were categorized into four types of indicators used to forecast rain: the emergence of butterflies; tree characteristics (producing shoots, flowering, and dropping water); wind direction, wind speed, and temperature; and wind sound. The first two types are based on seasonal changes in life forms, and the latter two use wind variations produced by synoptic pattern changes.

**Discipline:** Agro-meteorology

**Additional key words:** agriculture in Zambia, indigenous proverbs, meteorological observation, resilience, weather forecasting

### Introduction

There is growing concern about the increasing frequency of extreme climatic events and the impacts of global environmental changes. This concern is particularly serious in arid and semi-arid areas of sub-Saharan Africa, because rain-fed agriculture in these areas is predicted to be heavily damaged by climate change<sup>10</sup>. Although many preventative measures are currently being considered, improved knowledge of indigenous methods of weather forecasting should be available when planning how communities can prepare themselves to respond to changing weather patterns.

Several studies have examined indigenous knowl-

edge of weather. For example, Anandaraja et al.<sup>1</sup> investigated the relationships between indigenous practices and beliefs in India and local information and wisdom used to predict the weather. They concluded that such practices and beliefs played an important role in deciding agricultural schedules. Weatherhead et al.<sup>29</sup> compared the indigenous knowledge of the Inuit, living in Nunavut in northern Canada, with recorded meteorological patterns and found that their formerly extremely precise weather forecasting practices, especially using clouds, had become less accurate in recent decades due to climate change in the area. In sub-Saharan Africa and Kenya, the importance of indigenous knowledge for climate change and droughts has also been well investigated and discussed<sup>21,25</sup>, but no such studies have been performed in South Africa.

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This paper reports the results obtained in the research project ‘Vulnerability and Resilience of Social-Ecological Systems’ from 2006 to 2011, sponsored by the Research Institute for Humanity and Nature (RIHN).

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This may be attributable not to the lack of indigenous knowledge of weather forecasting but more likely to the lack of reliable local climate data for comparison.

The most significant weather-related disaster in sub-Saharan Africa is drought and the associated food insecurity. The two big famines in the Sahel from 1972 to 1974 and 1983 to 1985 have been relatively well studied by many disciplines, including meteorology. Several researchers have sought to determine the mechanism of rainfall variability that triggers famine conditions<sup>5,6,11,14,15</sup>. Le Barbe et al.<sup>16</sup> investigated rainfall variability in West Africa using high-resolution data and presented the spatial extent and structure of rainfall on intraseasonal and decadal time scales. Unfortunately, we do not know how or whether local people used indigenous knowledge to forecast the drought during those time periods.

There have been 15 agricultural droughts in Zambia over the past 40 years (1972–1973, 1979–1984 [five rainy seasons], 1986–1987, 1990–1995 [five rainy seasons], 1997–1998, 2000–2001, and 2004–2005), which seriously affected the agricultural production of maize and other products<sup>3,17,27</sup>. Moreover, recent changing climatic conditions have heightened the importance of meteorological study in semi-arid areas. In comparison with developed countries, however, meteorological observation networks in developing countries, including those in sub-Saharan Africa, remain sparse, and with a limited range of observation parameters. The deficiencies in meteorological data are exacerbated by the difficulty in carrying out fieldwork in these areas, but researchers must be able to observe local meteorological conditions and simultaneously collect information on indigenous knowledge to test the accuracy of local predictions.

The multidisciplinary research project “Vulnerability and Resilience of Social-Ecological Systems” conducted by the Research Institute for Humanity and Nature (RIHN) provided the opportunity to concurrently collect local meteorological and socio-economic data in a drought-prone, semi-arid region of Zambia. We then used the data collected as part of this project to explore the accuracy of indigenous weather predictions based on actual recorded meteorological phenomena.

### **Climate and agriculture in Zambia**

Zambia is located in southern Africa, covers an area of 752,615 km<sup>2</sup>, and lies between 22° to 34° E and 8° to 18° S. Most of the country is on a plateau at an elevation of 950 to 1500 m above sea level. The country has a subtropical climate and vegetation and three distinct seasons: a warm wet season from November through April, during which 95% of annual precipitation falls, a cool dry

winter season from May to July, with a daily mean temperature of 15 to 27°C, and a hot dry season in August to October, with temperatures peaking at 27 to 32°C<sup>7</sup>. Hachigonta et al.<sup>9</sup> investigated the onset and cessation dates of the rainy season in Zambia and pointed out that the typical onset of rains in Zambia was sometime in October or November, ceasing in March or April respectively, but from the 1980s to 2000s, the duration of the rainy season showed a declining tendency. The average annual rainfall varies from more than 1200 mm in the north, about 700 mm in the central part of the country and less than 700 mm in the south. The precipitations were cumulated and analyzed during the period October and April, including the months before and after the rainy season.

According to Jain<sup>7</sup>, Zambia is divided into three agro-ecological zones, where rainfall is the dominant climatic factor. Zone I covers the western and southern parts of the country and accounts for about 15% of the land area, receiving less than 800 mm of annual precipitation on average. This area used to be considered the “bread basket” of the nation, but over the last 20 years, has experienced low, unpredictable, and poorly distributed rainfall. Current meteorological data suggest that this is the driest zone, very draught-prone and with limited crop production potential.

Zone II covers the central part of the country and extends from east to west. It is the most populous zone, with over 4 million inhabitants, and has the highest agricultural potential. The soils here are relatively fertile, and the area receives about 800 to 1000 mm of rainfall annually, which is generally evenly distributed throughout the growing season. Zone III spans the northern part of the country and has a population exceeding 3.5 million. It receives more than 1000 mm of rainfall annually, but the high rainfall has resulted in nutrients leaching from the soils. Parts of the zone are suitable for cultivating late-maturing crops, but about 65% of the area in this zone has yet to be exploited for agricultural uses.

Zambia has an estimated nine million hectares of land (12% of its total area) suitable for cultivation and 16 million hectares suitable for rangeland grazing. Its major crops include maize, sorghum, millet, rice (paddy), wheat, cassava, ground nuts, sunflower, cotton, soya beans, mixed beans, and tobacco. Most are summer crops and almost entirely dependent on rains<sup>7</sup>. Zambia is one of the least-developed counties where agriculture is the major industry, the poverty ratio is as high as 70% and the proportion of the population suffering from malnutrition is as high as 50%<sup>8</sup>. The Southern Province in Zone I is the most sensitive in terms of climate variability, selecting the following research field.

## Methods

Local meteorological conditions have been recorded since 28 September, 2007 by automatic weather observation instruments installed by the RIHN project in three locations in Southern Province, Zambia. We collected meteorological data at three sites (A, B, and C; Figure 1) in Sinazongwe District, Zambia, from September 2007 to August 2010. The villages in which we collected information were scattered around A, B, and C, but their positions were too close, making it hard to plot in Fig. 1. Meteorological observation instruments (weather robots) were installed at Sianemba Village (site A: low elevation, 515 m; 17°05'S, 27°30'E) and Siachaya Village (site C: high elevation, 1090 m; 16°59'S, 27°20'E). These were powered by solar-charged batteries and installed in wide open areas devoid of vegetation near the center of each village. Observations of the air temperature and relative humidity (CS215-Lx temperature and relative humidity sensor with a 41303-5A radiation shield; Campbell Scientific Inc., Logan, UT, USA), air pressure (CS115 barometric pressure sensor, Campbell Scientific Inc.), solar radiation (CMP3 solar radiation sensor, Campbell Scientific Inc.), precipitation (CTK-15PC tipping-bucket rain gauges; Climatec Inc., Tokyo, Japan), and wind direction and speed (034B-Lx wind set, Campbell Scientific Inc.) were made at 30-min intervals and recorded by a data logger (CR1000, Campbell Scientific Inc.). Wind direction was recorded as instantaneous values, while other meteorological data (except precipitation) was recorded in the

form of 30-min means (the 30 min before data logging). Only one rain gauge was installed at site B (Kanego Village: middle elevation, 798 m; 17°06'S, 27°19'E) with a pulse data logger (HIOKI Inc., Nagano, Japan) used to record precipitation data. In this report, we used precipitation data at sites A and C, and wind data at site C because they are closely related to the indigenous climate information. Since the wind data from the first and second rainy seasons was problematic, the wind data from the third rainy season from 2009 to 2010 was used.

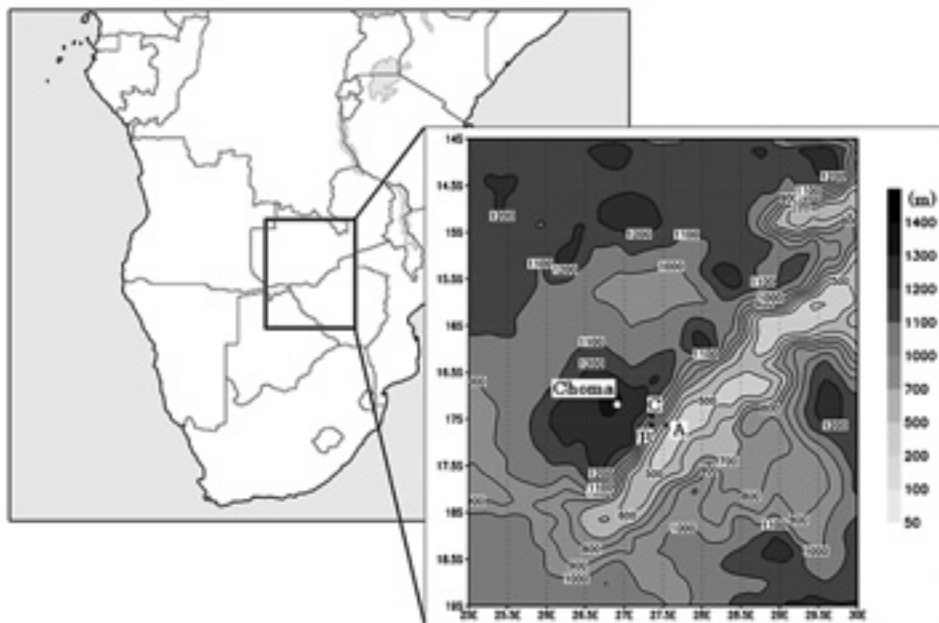
We conducted a social baseline survey in villages located around the three sites in April 2007 and collected information about their history, populations, sociological structures, agricultural practices, and local climate proverbs of weather indicators through group interviews<sup>24</sup>. The indigenous information and proverbs are summarized in the following sections:

## Results

### 1. Indigenous Information about the Local Climate and Agriculture

Indigenous information was categorized into three groups according to indicators of expected weather and beliefs about weather: the relationship among elevation, topography, and local climate; the importance of the beginning of the rainy season; and the impact of lowland flooding. In Table 1 the indigenous knowledge as reported by local residents in the area was summarized.

(1) Relationships among elevation, topography, and local



**Fig. 1. Locations of research sites**

A; flat area near Lake Kariba, B; hill slope area, and C; hill top area.

climate

Table 1-a): This information was provided by people who had lived in a lowland area near Lake Kariba but had moved upland and built Mugilo Village. They said that the climate in the upland area was better.

Table 1-b): The minimum temperature sometimes falls below 0°C during the dry season in upland areas. Damage to dry season crops has been observed in both Gwembe Valley and in the plateau (personal communication, Dr. Elizabeth Colson, professor emeritus, the University of California at Berkeley and honorary doctor, University of Zambia).

(2) The importance of the beginning of the rainy season

Table 1-c), d), e): The first rain is crucial to the timing of planting in the semiarid tropics, and used by farmers to indicate the rainy season as a whole. It might be expected that the precipitation in the early part of the rainy season could be used to indicate the amount of precipitation for the entire season because early rains may indicate that a rain system, such as the Inter Tropical Convergence Zone (ITCZ), has arrived earlier than normal<sup>26</sup>. However, as will be discussed later, no statistically significant correlation was found between the amount of precipitation in the early season months and the total precipitation in the entire rainy season.

Table 1-f): January is crucial for the crop's growing

stage. If there is sufficient rainfall at the beginning of the rainy season, sometimes January weather easily loses that advantage.

(3) Lowland floods

Table 1-g): In the 2006–2007 rainy season, it first rained on 19 November in Siameja Village. Since that date was delayed from that of a normal year, farmers planted in the river bank fields. On 21 January, 2007, these fields were flooded and crops were swept away. Those villages suffered double damages — first from the dry spell and second from the flood — in the 2006–2007 rainy season.

Table 1-h), i): Floods have been a big problem in the lowland part of the study area and seem to occur nearly in 5-year cycles. Given the ENSO (El Niño and the Southern Oscillation) phenomena, which normally appear to have a cycle of around five years from 1982<sup>4</sup>, they might be related to such cyclic phenomena. In the 2006–2007 rainy season, the sea surface temperature in the tropics showed an El Niño-like pattern, Australia experienced drought and Jakarta, Indonesia, experienced flooding. Nevertheless to say, there is little doubt that ENSO influences global weather, including South Africa<sup>18,20,23</sup>. Even in northern Japan, a distinct 5-year cycle has recently emerged in the boreal summer months (June, July and August) weather<sup>12</sup>. ENSO may also affect the southern

**Table 1. Indigenous Information about the Local Climate and Agriculture**

	Contents	Village name	Elevation (m)
a	Precipitation in upland areas exceeds that in lowland areas.	Mugilo	1018
b	In June and July crops are sometimes damaged by frost, especially in the valley.	Sikalindi Mugilo	1038 1018
c	A delay in the onset of the rainy season significantly damages crops.	Sikalindi	1038
d	The beginning of the rainy season is crucial for planting crops.	Kanego	968
e	When it rains in October, farmers will start by planting in upland fields in their village, because they believe that rain in October indicates a good rainy season and that plants will grow well, even in the dryer fields at relatively high elevation. When it does not rain in October and November, farmers believe that drought will occur and begin planting in fields near the river to enhance food security from these low-lying wetland areas.	Siameja	535
f	Dryness in January is the worst for the crops.	Chande	526
g	It rained heavily on 21 January, 2007 and flooding occurred. All crops (maize, sorghum, millet, etc.) in Nangombe river bank fields were swept away.	Lusinga Kalanguwa Siameja	528 507 535
h	Floods occur in 5-year cycles.	Lusinga Siameja	528 535
i	The main floods in the lowland areas occurred in January 1978 (on the same scale as in 2007), February 1985 (small-scale), and March 2003 (small-scale).	Siameja	535

part of Africa in general, including our study area<sup>9,20,26</sup>. A more detailed discussion will be presented later in this report.

## 2. Proverbs for Forecasting the Weather

We collected 10 proverbs that addressed the topic of weather prediction and grouped them into four categories: emergence of butterflies; tree characteristics (producing shoots, flowering, and dripping water); wind direction, wind speed, and temperature; and wind sound. We then evaluated the proverbs in terms of possible scientific explanations by examining the potential relationships between the various biological or geographical phenomena and meteorological phenomena, and sought reliable indicators for weather forecasting. These proverbs were summarized in Table 2.

### (1) Emergence of butterflies

Table 2-a): Different types of butterflies develop on different plants, and the growing stage of the plants is affected by seasonal progressions each year. The appearance of certain butterflies may reflect year-to-year variations in the timing of the rainy season, and may therefore be a good index for predicting the beginning of the rainy season.

### (2) Trees

Tables 2-b), c), d), e): Seasonal changes in the amount of soil water control the growing stage of trees (Fig. 3), and the water-dripping phenomenon possibly due to the hydraulic-lift phenomenon<sup>2</sup>. Figure 2 shows the impressions made by water dripping from a mukololo tree. Although this tree was located in a dry upland field and the photo was taken just after noon local time at the end of the dry season, with the temperature exceeding 30°C, water dripped from the tree like rain. As we showed in Fig. 7, interestingly, the 2009–2010 rainy season did indeed show a greater than average total rainfall at Choma.

### (3) Wind direction, wind speed, and temperature

Tables 2-f), g), h): Seasonal change is produced by the alternation of synoptic patterns, meaning farmers may recognize the beginning and end of the rainy season using wind direction, wind strength, and temperature. Temperatures at our observation site peaked in the year from October to December, immediately before and after the onset of the rainy season, meaning the hot temperature in November does not contradict our meteorological observation data. Also, temperatures declined gradually during the rainy season, at the end of which, the rate of temperature decline accelerated and temperatures fell

**Table 2. Proverbs for Forecasting the Weather**

	Contents	Village name	Elevation (m)
a	When white butterflies appear, the rainy season will soon follow. When black butterflies appear, farmers will get rain for planting.	Siabunkululu	1023
b	When acacia trees produce shoots, the rainy season will end.	Siabunkululu	1023
c	From September to October, if water drips from the mukololo tree ( <i>Lonchocarpus capassa</i> ; Fig. 2) the rainy season will be good. If water does not drip, farmers should first plant in lowland fields. If it then rains, they should plant on the slopes and hilltop fields.	Sikalindi	1038
d	If the mutobo tree ( <i>Dombeya rotundifolia</i> ; Fig. 3) produces shoots from September to October, a good rainy season will follow.	Mugilo	1018
e	Flowering of the mukololo tree (Fig. 2) is a good indicator for planting. Normally it blooms in around September.	Kanego	968
f	When wind speed increases strongly, the rainy season will end. During the dry season, when wind blows easterly, a westerly shift in the wind direction indicates that a strong rain is coming.	Siabunkululu	1023
g	Easterly winds bring rain in the rainy season. If easterly winds are not stable, it doesn't rain. From October to November, an easterly wind blows, and then the rainy season starts.	Sikalindi	1038
h	If it rains heavily and then heats up in November, the rainy season will be good.	Fodowi	605
i	When people hear the sound of wind at the beginning of the rainy season, it will rain in three to four days.	Siabunkululu	1023
j	If people hear a wind sound (spiritual singing) from the place between two specific hills, there will be good rain.	Fodowi	605

continuously until June (figures not shown).

(4) Wind sound

Table 2-i), j): We were unable to confirm the precise significance of the wind sound, but we assumed it was attributable to strong wind blowing between the mountains, hills, and/or valleys with distinct changes of wind direction and speed. Wind variations are produced by synoptic-scale disturbances, allowing farmers to forecast rain using wind variations. It is interesting that people imagine the sound of wind as the singing of spiritual beings, but this applies only to localized areas on the landscape.

**Discussion**

We compared the meteorological data recorded from the 2007–2010 three rainy seasons with predictions based on indigenous knowledge, including the proverbs. First, we compared Table 1-a) recorded in Mugilo Village (*Precipitation in the upland exceeds that in the lowland*) with recorded precipitation data from upland (Siachaya Village) and lowland (Sianemba Village) areas, detailed for the 2007–2008 rainy season in Fig. 4 and statistically summarized for the three rainy seasons in Table 3. Although residents of Mugilo Village suggested that precip-

itation was greater at higher elevations, total precipitation in the three rainy seasons was higher in the lowland areas; 1564 mm at Sianemba Village and 1334 mm at Siachaya Village in average, respectively (Table 3). However, the frequency of rainy days was higher on average in upland (88 days) rather than lowland areas (74 days), respectively (Table 3). This may mean that the intensity or duration of the precipitation in the lowland area is stron-



**Fig. 3.** Photo of a mutobo tree producing shoots (*Dombeya rotundifolia*; photo taken on 8 April, 2007)



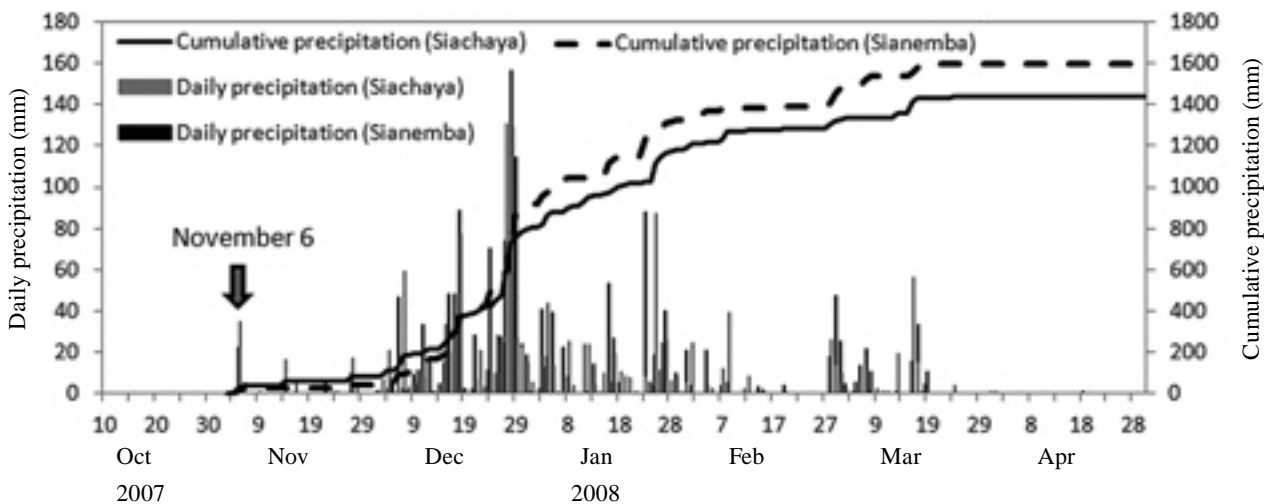
**Fig. 2.** Photos of (a) a mukololo tree (*Lonchocarpus capassa*) and (b) a water pool under the tree created by water dripping from the tree (photo taken at 13:00, 8 October, 2009)

ger or longer as compared with the upland site. These circumstances can be seen in Fig. 4. Since the lowland area again had more rainfall than the upland area in the 2007–2010 rainy season, one possible explanation could be that the lowland area has warmer temperatures that produce convection currents, whereas the upland area has calmer weather resulting from the upper general wind pattern and gentle rain from stratus clouds. People living in upland areas may experience more rainy days than those at lower altitudes and therefore perceive the precipitation as greater in their areas even though the opposite may be true and the difference may be small in any case.

We then examined a proverb at Table 2-f) recorded in Siabunkululu Village (*During the dry season when wind blows easterly, a westerly shift in the direction of the wind indicates that strong rain is coming*). We considered seasonal variations in wind speed and direction overnight and during the day by selecting two representative times: 0400 (night) and 1300 (day) from June to following March at Siachaya Village (Fig. 5). There were no clear seasonal variations in wind speed or direction at night, the wind speed oscillated above and below 1 m/s from the dry season through to the end of the rainy season and wind direction varied considerably, but was dominantly around 30° (Fig. 5a). Conversely, there was a

change in daytime wind direction at the start of the rainy season in around early November. Namely, until mid-November, the daytime wind direction remained stable at around 100° but clearly became unstable at the beginning of the rainy season (Fig. 5b). These observations indicate that the major variations in daytime wind direction and speed correspond to the change from dry to rainy season. To see the synoptic field, a low-pressure front did indeed come from the west and passed over the study area around 6 November, 2007 (Fig. 6)<sup>13</sup>. Since Southern Africa is significantly affected by the Pacific South American (PSA) teleconnection pattern<sup>19</sup>, this cyclone also possibly belongs to that wave pattern. When the cold front passed, the wind direction changed from easterly to westerly as shown in Fig. 5. Concerning the wind speed in the proverb (Table 2-f), at high land we found none of the distinct changes mentioned (Fig. 5-b). It's possible that local people may be sensitive to atmospheric changes and capable of noting small differences in wind speed.

Finally, we investigated the historical record of precipitation and compared it to indigenous knowledge of weather predictions. The Choma National Meteorological Observation Station is located in Southern Province (16°49'S, 26°58'E) about 90 km northwest of our research area and at an elevation of about 1400 m (shown in Fig. 1).



**Fig. 4. Mean daily and cumulative precipitation in Siachaya Village (1090 m) and Sianemba Village (515 m) from 10 October, 2007 to 30 April, 2008**

Values are averaged 12 data points at each location.

**Table 3. Precipitation and precipitation days in three rainy seasons**

	Rainy season	2007/2008	2008/2009	2009/2010	average
Precipitation	Siachaya	1396	1345	1262	1334
Precipitation days	Siachaya	86	94	83	88
Precipitation	Sianemba	1597	1419	1675	1564
Precipitation days	Sianemba	75	80	68	74



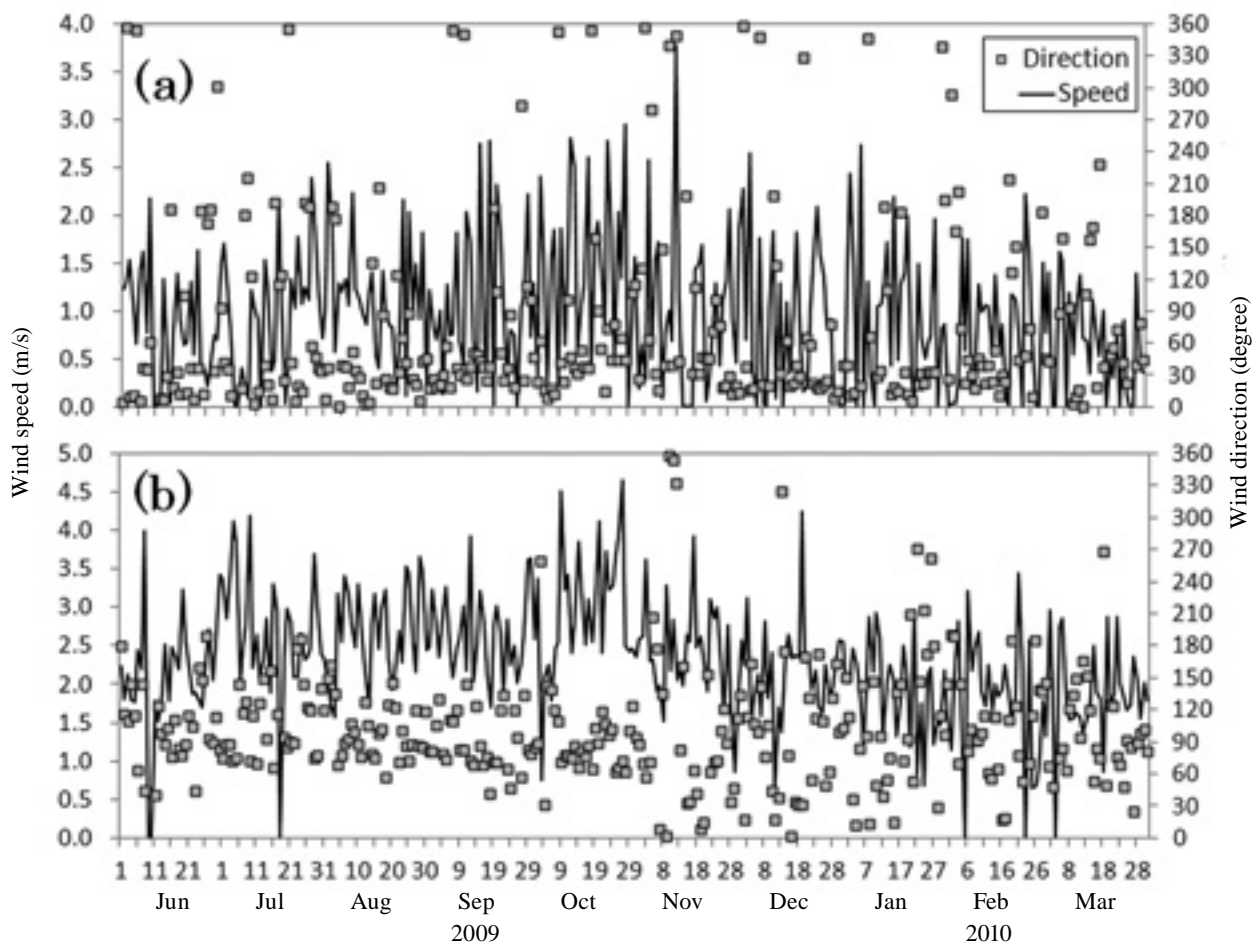
We used precipitation data from this station to represent the historical climatological values for our study area and analyzed temporal variations in precipitation on yearly and monthly time scales.

Rain in the early stage of the rainy season is crucial to farmers because this corresponds to the planting period<sup>22</sup>. Figure 7 shows the time series of monthly precipitation for the early part of the rainy season (October, November, and December) and the seasonal deviation (cumulative precipitation from October to the following April) from 1950 to 2009. The 60-year mean is 797 mm and the standard deviation is 194 mm. An annual variation is quite apparent — rainfall in 12 of the years was dry or relatively low, and during 10 relatively wet years; higher, in one standard deviation from the long-term mean.

On a time scale of decades, each period had one or two dry and wet years over one sigma, but there were three wet years in the 1970s and four dry years in the 1990s. During the 1960s and 1970s, all dry years coincid-

ed with El Niño events, but in about four wet years only one year of 1973 coincided with the La Niña event. Consequently, five out of eight cases corresponded to the ENSO events during the 1960s and 1970s, and a high rate of coincidence is apparent. Conversely, in the 1980s and 1990s, most of the dry years did not coincide with the El Niño year except for 1991, but two out of three wet years coincided with the La Niña event. In the decade after 2000, there were two El Niño and three La Niña events, but only one La Niña year of 1997 coincided with the wet year over one sigma. Generally, in the 1960s and 1970s, the decades of dry and wet years effectively corresponded to the ENSO events, but from the 1980s, their agreements lost weight.

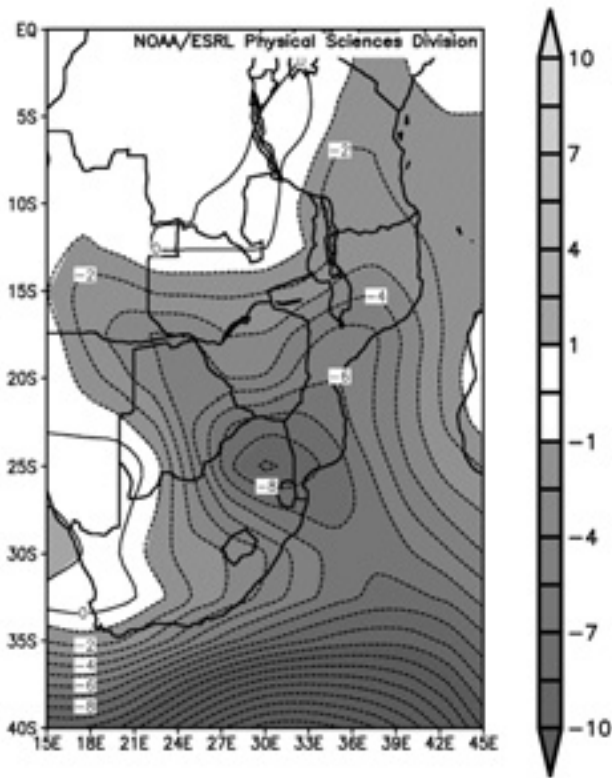
According to Nicolson and Kim<sup>20</sup>, the effects by ENSO are strong in eastern and southern Africa and positive anomalies of precipitation occur during half the ENSO cycle and negatives during the second half. Since our statistical analysis was less complex than Nicolson and Kim<sup>20</sup>, the rate of correlation between precipitation



**Fig. 5. Daily variations in hourly mean wind speeds and directions at (a) 0400 hours and (b) 1300 hours from 1 June, 2009 to 31 March, 2010 at Siachaya Village**

Wind speed was calculated as an arithmetic mean and wind direction as a vector mean. We initially separated the east–west (u) and north–south (v) components and then computed hourly averages.



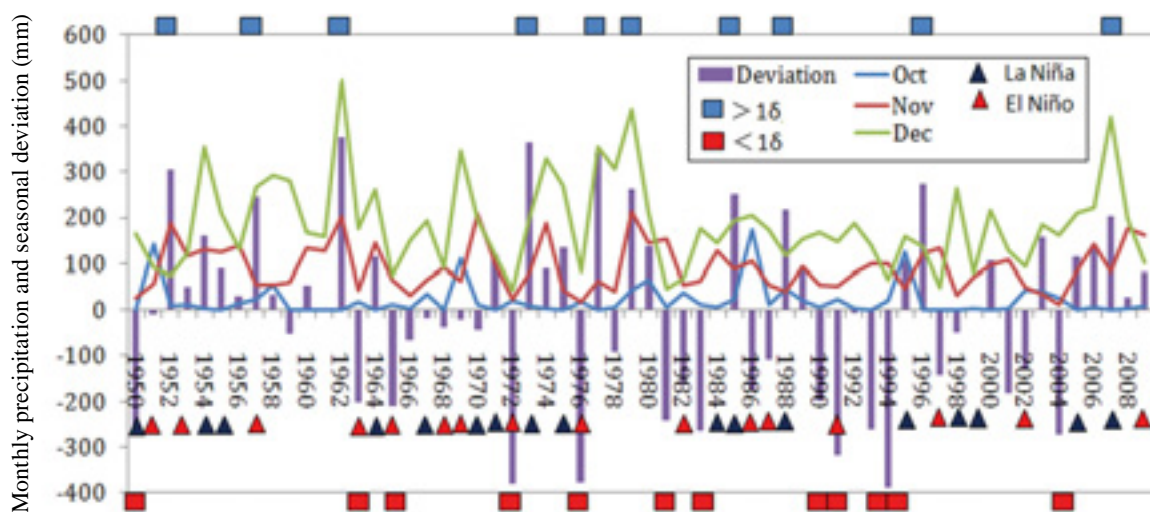


**Fig. 6. Sea level pressure (hPa) deviation map from 6 November, 2007**

Source: Earth System Research Laboratory<sup>13</sup> (<http://www.esrl.noaa.gov/psd/data/composites/day/>; accessed 24 October, 2011).

and ENSO seems positive, as in Nicolson and Kim<sup>20</sup> in the 1960s and 70s, but from the 1980s, the tendency indicated by Nicolson and Kim<sup>20</sup> seems unclear. At this point, the one possibility emerges that they used areal average data, whereupon the local characteristic features such as these at Choma might be neglected in terms of result. Of course we should consider how the ENSO cycle varies on a decadal scale, meaning the effect of ENSO may also have changed over different decades<sup>28</sup>.

Local residents stressed the importance of planting precipitation in the early stages of the rainy season — Tables 1-c), d), and e). We compared monthly precipitations and found no statistically significant relationship between the amount of rain in October and that in November–April (NDJFMA), between levels in October–November and DJFMA, or between levels in October–December and JFMA (data not shown). As shown in Fig. 6, the first rain in the 2007–2008 rainy season was produced by a low-pressure front passing to the south of Zambia. Therefore, it is possible that some rainfall events in the early stage of the rainy season are produced by synoptic activity to the south of Zambia and do not directly coincide with seasonal variations in the northern ITCZ, meaning no statistical correlation between early season and annual rainfall amounts. A qualitative examination of December precipitation levels indicate that they may be related to total precipitation (see the 1962–1963, 1977–1978, 1979–1980, and 2007–2008 wet seasons in Fig. 7). The mean December precipitation is 188 mm, which is the second highest behind that of Janu-



**Fig. 7. Time series of monthly precipitation for the early part of the rainy season (October, November, and December) and the seasonal deviation of the cumulative precipitation (from October to the following April) from the long-term average from 1950 to 2009**

El Niño, La Niña, and variations in annual precipitation over and under one standard deviation are also illustrated.

ary (204 mm). There is also significant variation, with a standard deviation of 100 mm. According to Hachigonta et al.<sup>9</sup>, ENSO is indeed more useful from a diagnostic than prognostic perspective for the onset and cessation of rainy season in the 1980s and 1990s. Therefore, if we were to find a significant relationship between December precipitation and ENSO and other cyclic variations, these findings could be useful for agriculture. To date, however, no identifiable patterns have been found and it remains difficult to forecast the amount of precipitation during the rainy season. Consequently, it seems even more important to investigate indigenous weather knowledge because the scale of official weather forecasts is generally too coarse to reflect local variations.

### Summary and conclusion

The results from this study show that indigenous knowledge of weather indicators, including proverbs, can be used to predict meteorological phenomena, and the relationships between certain indicators and weather predictions were verified by observed weather patterns and other data, but not in certain cases (e.g. the upland and lowland rain). In other countries, local weather predictions have been shown to be useful. Anandaraja et al.<sup>1</sup> investigated the relationships between indigenous practices and beliefs in India and the weather forecast information from the Indian Meteorological Services and found that such practices and beliefs played a useful role in deciding agricultural schedules. It would be useful to develop standard methods for collecting indigenous weather information and seek correlations over a much wider area, especially the scope of local knowledge for predicting floods and cyclic fluctuations based on global scale-phenomena, such as ENSO. Local knowledge, however, may not be effective in a period of rapid climate change, as shown by the Inuit at Nunavut in northern Canada<sup>29</sup>. It is possible that the indigenous information gathered from Sinazongwe in Zambia has implications for understanding how local climate change is reflecting global variations, and could be a useful tool in estimating potential local environment challenges under future climate change.

The results presented in this paper are merely examples of indigenous information and weather forecasting proverbs, but the meteorological observations in this and other areas should provide high quality data that will be useful in gaining a better understanding of the importance of this and additional indigenous information. Our own investigation showed the importance of continuing to collect information on locally-used weather indicators and matching them with observed meteorological data, both to improve our global understanding of weather and

climate and because local people rely upon them for agricultural planning. More detailed analysis using observed meteorological data is needed in future.

### References

1. Anandaraja, A. et al. (2008) Indigenous weather and forecast practices of Coimbatore District farmers of Tamil Nadu. *Indian J. of Traditional Knowledge*, **7**, 630–633.
2. Brooksbank, K. et al. (2011) The fate of hydraulically redistributed water in a semi-arid zone eucalyptus species. *Tree Physiol.*, **31**, 649–658.
3. Commonwealth Forestry Association—Zambia Branch (2011) <http://www.cfa-international.org/zambia/introduction%20to%20zambia.htm> [Accessed 24 Oct 2011]
4. Fedorov, A.V. et al. (2003) How predictable is El Niño? *Bulletin of the American Meteorological Society*, **84**, 911–919.
5. Folland, C.K. et al. (1986) Sahel rainfall and worldwide sea temperature 1901–1985. *Nature*, **320**, 602–607.
6. Fontaine, B. & Janicot, S. (1996) Sea surface temperature fields associated with West African rainfall anomaly types. *J. Climate*, **9**, 2935–2940.
7. Jain, S. (2006) An Empirical Economic Assessment of Impact of Climate Change on Agriculture in Zambia. Pretoria, Center for Environmental Economics and Policy in Africa (CEEPA), University of Pretoria. CEEPA Discussion Paper, **27**, 1–33.
8. Japan Association for International Collaboration of Agriculture and Forestry (2008) Agriculture and forestry in Zambia—present situation and issues for development—. JAICAF, **77**, pp.64.
9. Hachigonta, S. et al. (2008) An analysis of onset data and rainy season duration over Zambia. *Theor. Appl. Climatol.*, **91**, 229–243.
10. Hassan, R.M. (2010) Implications of climate change for agricultural sector performance in Africa: Policy challenges and research agenda. *J. African Econom.*, **19**, AERC SUPPLEMENT 2, ii77–ii105.
11. Hastenrath, S. (1990) Decadal scale changes of the circulation in the tropical Atlantic sector associated with Sahel drought. *Int. J. Climatol.*, **20**, 459–472.
12. Kanno, H. (2004) Five-year cycle of north-south pressure difference as an index of summer weather in Northern Japan from 1982 onwards. *J. Meteorol. Soc. Jap.*, **82**, 711–724.
13. Kalnay, E. & Coauthors (1996) The NCEP/NCAR 40-year reanalysis project. *Bull. Amer. Meteor. Soc.*, **77**, 437–471.
14. Lamb, P.J. (1983) West African water variations between recent contrasting Sub Saharan droughts. *Tellus*, **35A**, 198–212.
15. Lamb, P.J. & Pepler, R.A. (1992) Further case studies of topical Atlantic surface atmospheric and oceanic patterns associated with sub-Saharan Drought. *J. Climate*, **5**, 476–488.
16. Le Barbe, L. et al. (2002) Rainfall variability in West Africa during the years 1950–90. *J. Climate*, **15**, 187–202.
17. Lekprichakul, T. (2007) Impact of 2004/2005 drought on Zambia's agricultural production: Preliminary results. Research Institute for Humanity and Nature, FY2006 PR

- Project Report, 69–82.
18. Lindesay, J. A. (1988) South African rainfall, the Southern Oscillation and a southern hemisphere semi-annual cycle. *J. Climatol.*, **8**, 17–30.
  19. Mo, K.C. & Paegle, J.N. (2001) The Pacific-South American modes and their downstream effects. *Int. J. Climatol.*, **21**, 1211–1229.
  20. Nicholson, S.E. & Kim, J. (1997) The relationship of the El Niño-southern oscillation to African rainfall. *Int. J. Climatol.*, **17**, 117–135.
  21. Nyong, A. et al. (2007) The value of indigenous knowledge in climate change mitigation and adaptation strategies in the African Sahel. *Mitig. Adapt Strat. Glob. Change*, **12**, 787–797.
  22. Omotosho, J.B. et al. (2000) Predicting monthly and seasonal rainfall, onset and cessation of the rainy season in West Africa using only surface data. *Int. J. Climatol.*, **20**, 865–880.
  23. Reason, C.J.C. et al. (2000) ENSO and climatic signals across the Indian Ocean basin in the global context: Part I, Interannual composite patterns. *Int. J. Climatol.*, **20**, 1285–1327.
  24. Sakurai, T. (2008) Asset holdings of rural households in Southern Province, Zambia: A report from census in the study villages. Research Institute for Humanity and Nature, FY2007 PR Project Report, 59 (abstract).
  25. Speranza, C. I. et al. (2010) Indigenous knowledge related to climate variability and change: insights from droughts in semi-arid areas of former Makueni District, Kenya. *Climatic Change*, **100**, 295–315.
  26. Toulmin, C. (2010) *Climate Change in Africa*. Zed Books, London, pp.172.
  27. VAC (Vulnerability Assessment Committee) (2006) 2006 Comprehensive vulnerability assessment and analysis concept paper. Zambia Vulnerability Assessment Committee, Lusaka, Zambia.
  28. Wang, B. (1995) Interdecadal changes in El Niño onset in the last four decades. *J. Climate*, **8**, 267–285.
  29. Weatherhead, E. et al. (2010) Changes in weather persistence: Insight from Inuit knowledge. *Global Environmental Change*, **20**, 523–528.