Interannual variation of seasonal rainfall in South Zambia

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1. Introduction

The amount of rainfall and its seasonal characteristics are important factors in Zambia, because its economy depends on rain-fed agriculture. Therefore, analyses of historical rainfall patterns are useful from a scientific perspective, but also in terms of understanding Zambian culture. In terms of "resilience", the responses to a previous shock event, for example, a drought, may affect current drought prevention activity and the behavior of farmers. In this paper, we describe the rainfall climatology and the rainfall trends over the last 40 years in Zambia. The final goal of this study is to evaluate the conditions over the target years of the project (2006–2011) compared with long-term conditions (over the last 50 years). This paper does not present measurement data from the current project, but instead shows rainfall data archived by the Zambia Meteorological Department. As well, we present gridded precipitation climatology data (shown in section 2.4) and satellite (radar) estimates (2.3).

2. Data

Recently, many rainfall estimates have been obtained using satellite data. However, the time-series of such estimates are not long enough to reveal long-term trends. Furthermore, these estimates need to be confirmed by comparisons with direct rain-gauge measurements, especially in desert areas. For these reasons, we have mainly used rain-gauge measurement data in this study (2.1, 2.2).
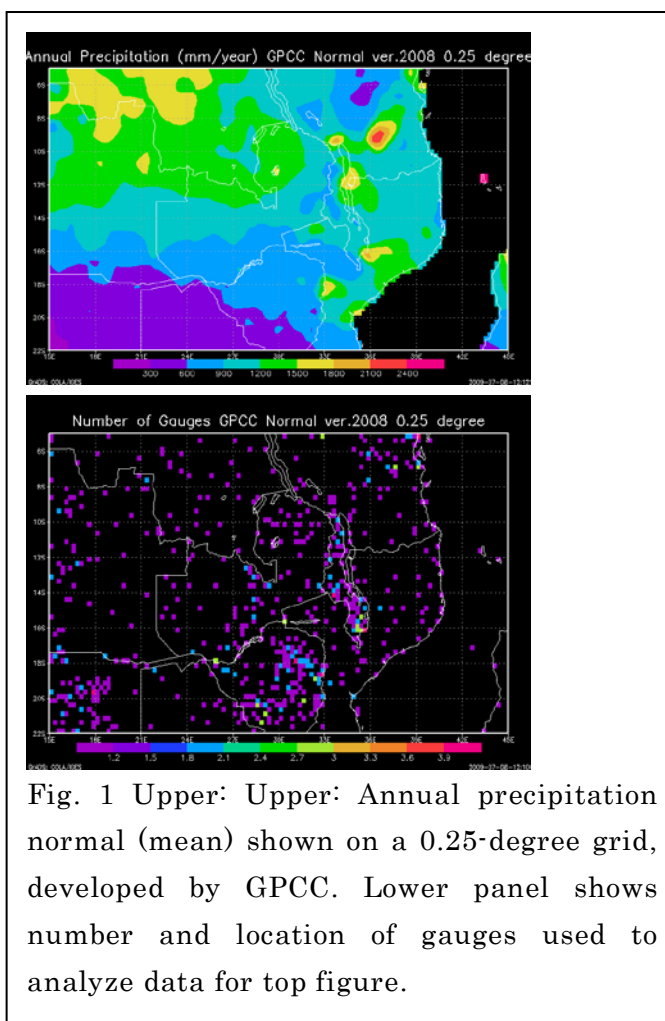

Fig. 1 Upper: Upper: Annual precipitation normal (mean) shown on a 0.25-degree grid, developed by GPCC. Lower panel shows number and location of gauges used to analyze data for top figure.

2.1 Monthly rainfall station data

The monthly rainfall station data were obtained from the Zambia Meteorological Department (ZMD).

At the beginning of this project, we obtained monthly precipitation data collected from 40 stations across Zambia from 1961 to 2003. Some of the information regarding station locations appeared to be incorrect, in that some of the stations appeared to be located outside of the national boundary. These data were checked and corrected (cf. Figure 3a, Saeki, 2008). Then data updated to 2006 were obtained.

2.2 Daily rainfall data

The daily rainfall data for Zambia were compiled by the Zambia Meteorological Department. We obtained daily precipitation data for Zambia from 1978 to 2009. Some stations have data updated to 2007/2008.

2.3 Precipitation Radar (PR) of Tropical Rainfall Measuring Mission (TRMM)

TRMM/PR is a powerful tool to show rainfall patterns, including those on orographically complex terrain. We used "near surface rain" of PR2A25 path data to construct a 0.05-degree grid (approximately 5-km mesh) to show precipitation climatology data in the period from 1998 to 2007.

2.4 Global Precipitation Climatology Center (GPCC)

The GPCC is an international organization that operates within the German Meteorological Service (DWD). They produce monthly precipitation grid data. Here, we used only the climate normal values (one of their products created in 2008) and some station information.

3. Results
3.1 Climatology

Figure 1 shows annual precipitation data obtained by the GPCC. The maximum rainfall occurs in northwestern Zambia, and the amount of rainfall decreases to the southeast. The South District of Zambia receives 600–900 mm rainfall per year, and thus, this area is a semi-arid zone. The lower panel of Figure 1 shows the locations of the rain gauges across Zambia. The network of rain-gauges shown in this map, including those in surrounding countries, appears to be sufficient to study the relationship between rainfall and synoptic meteorological conditions.

TRMM/PR is one of the most powerful tools to depict rainfall patterns over land area, including orographically complicated terrain. Figure 2 shows a 10-year composite of TRMM/PR monthly rainfall patterns. Northwestern parts of Zambia receive more rainfall in October, November, and March, while there is a uniform pattern of rainfall across Zambia in December and January.
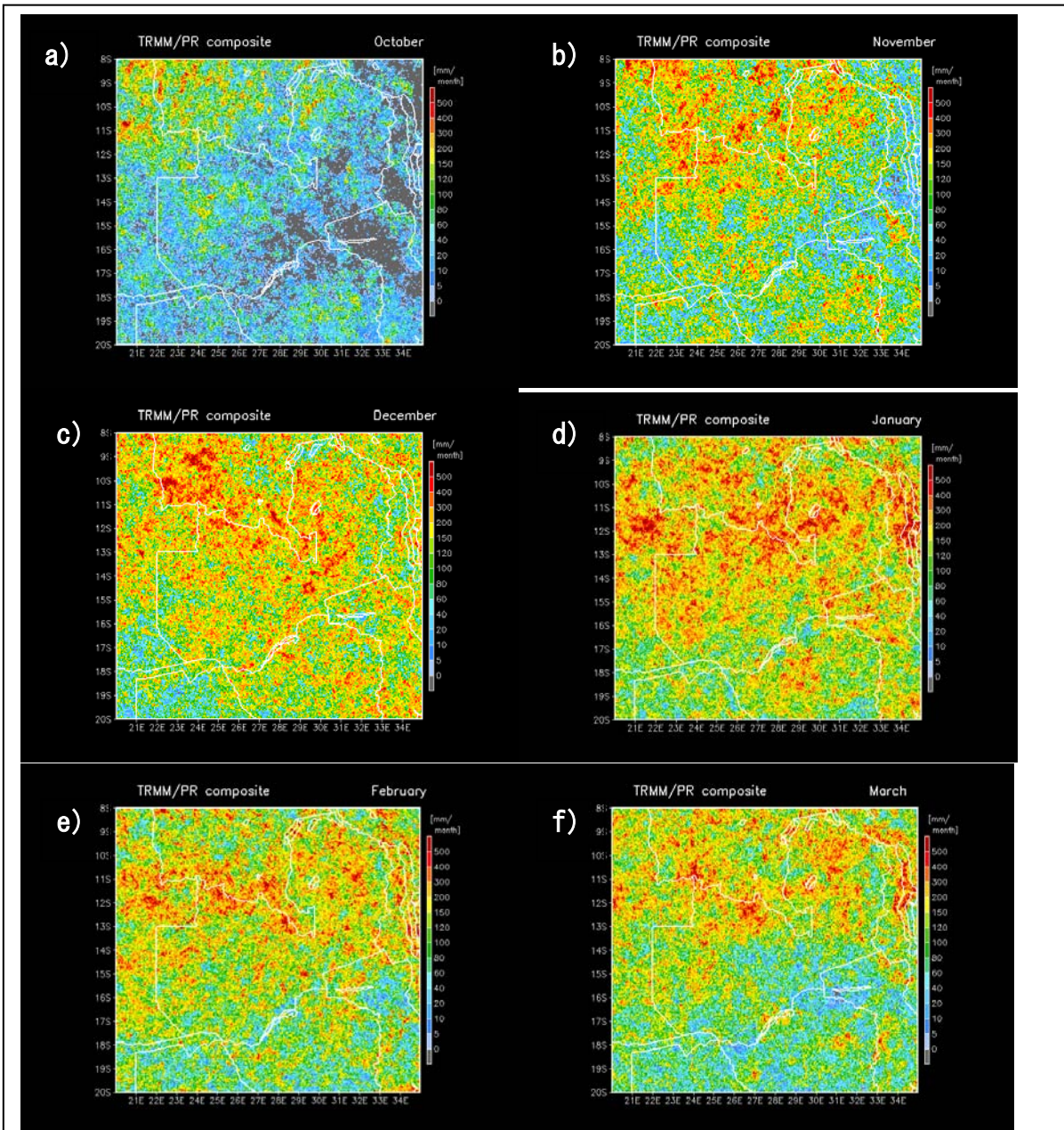
Figure 2.　Monthly composite pattern (October to March) of "near surface rain" data from Precipitation Radar on board TRMM. Unit (mm/h) was converted into mm/month.

3.2 Trend of seasonal precipitation

Figure 3 shows seasonal rainfall over time during the period from 1961 to 2003. For this figure, we chose data from three stations (Chipata, Lusaka, and Livingstone) along the northeast-southwest national boundary. At all of these stations, there was a decrease in rainfall from at least the 1970s to the early 2000s. Some rainfall peaks are coincident at several

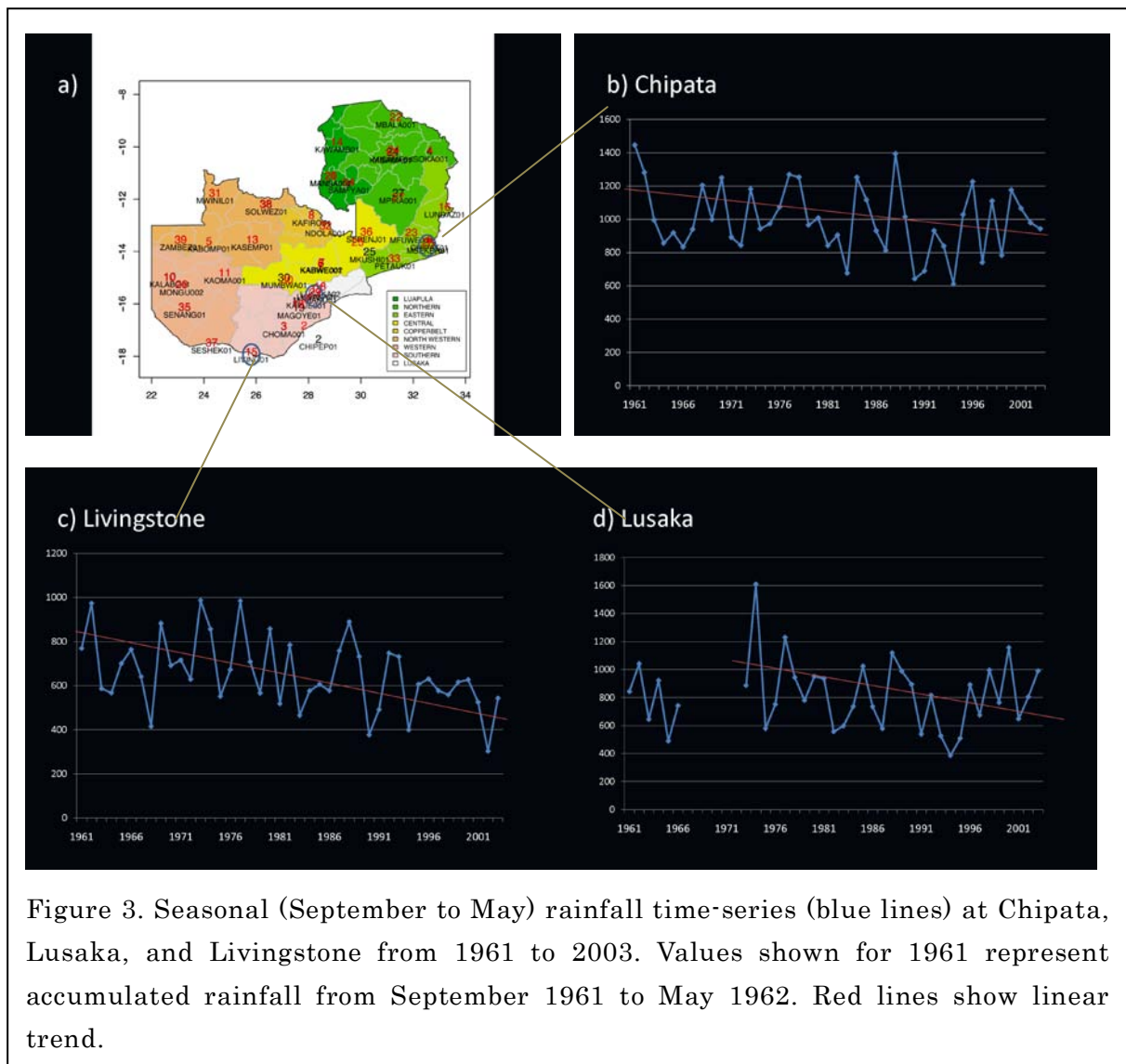stations, but they do not always match. Hence, further discussions will be focused on the South Province.

Figure 3. Seasonal (September to May) rainfall time-series (blue lines) at Chipata, Lusaka, and Livingstone from 1961 to 2003. Values shown for 1961 represent accumulated rainfall from September 1961 to May 1962. Red lines show linear trend.

3.3 Relationship with El Nino/Southern Oscillation (ENSO)

The ZMS observation station nearest to the project site is at Choma. Figure 4 shows the annual (August–July) rainfall time-series at Choma, Lusaka, and Livingstone from 1978 to 2007. The three time series show very similar patterns of fluctuations. In general, there was less rainfall at all of these sites in El Nino years, and more rainfall in La Nina years. However, this trend was not always observed. In 2006 and 2007, the time series at Choma differed from those at the other two sites. Therefore, to understand the rainfall variability and to compare it with the project observation site, it may be important to analyze rainfall patterns using satellite data.

Figure 5 shows the composite rain-rate pattern for December 2006 and December 2007. Although TRMM/PR has a large sampling bias problem, it shows clear differences in rainfall patterns. In particular, it highlights the rainfall maxima around Lake Kariba in December 2007.
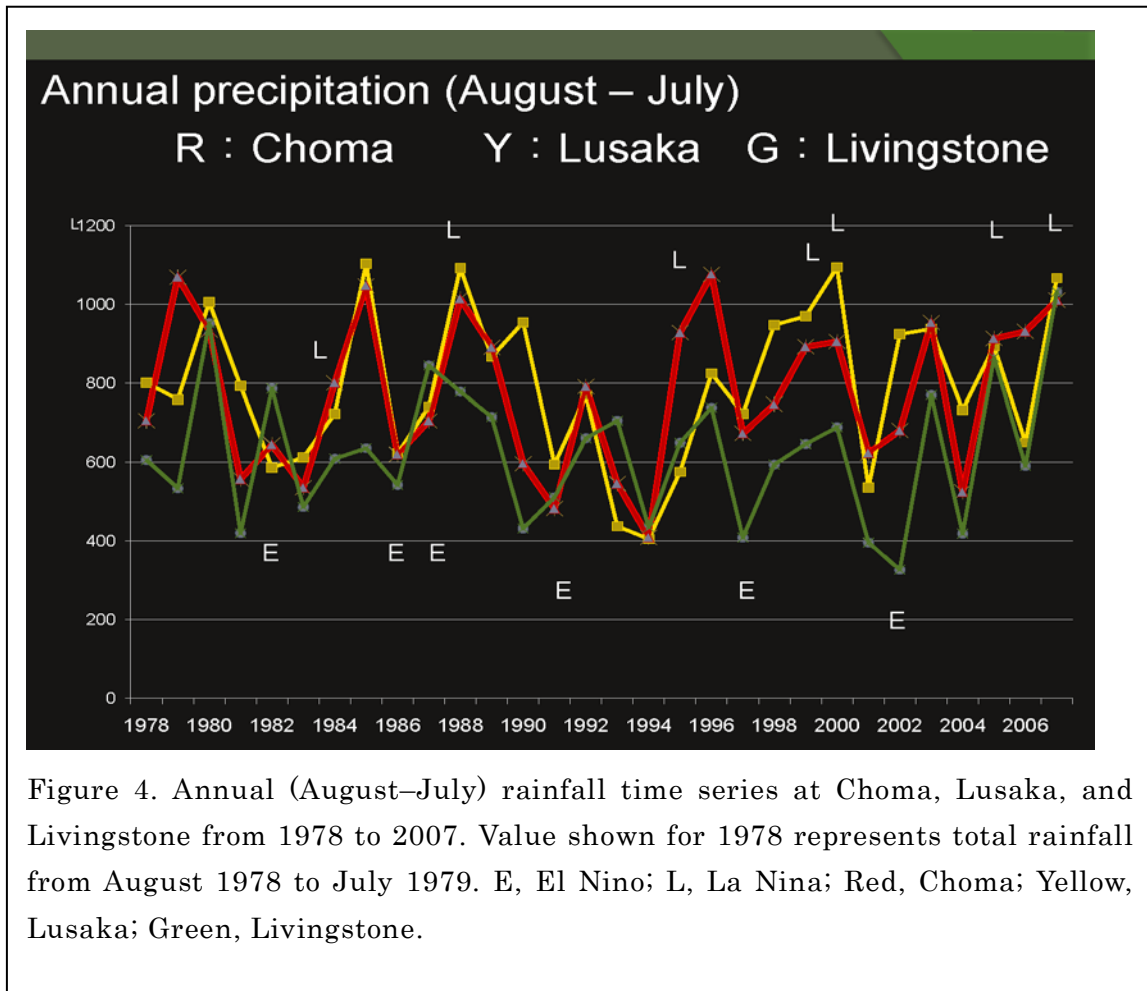

Figure 4. Annual (August–July) rainfall time series at Choma, Lusaka, and Livingstone from 1978 to 2007. Value shown for 1978 represents total rainfall from August 1978 to July 1979. E, El Nino; L, La Nina; Red, Choma; Yellow, Lusaka; Green, Livingstone.

3.4 Daily rainfall change at Choma

Figure 6 shows accumulated rainfall over time at Choma. This type of rainfall data is important for agricultural purposes. As shown in Figure 4, in general, there is less rainfall at this site in El Nino years. Hence, a severe drought period occurred in 1982/1983 and 1991/1992. However, there was also less rainfall in 1999, even though it was a La Nina year. In terms of agricultural production, it is important to clarify which patterns of rainfall are more harmful. It is also important to understand the dominant factors affecting such rainfall patterns, including climate patterns such as El Nino.
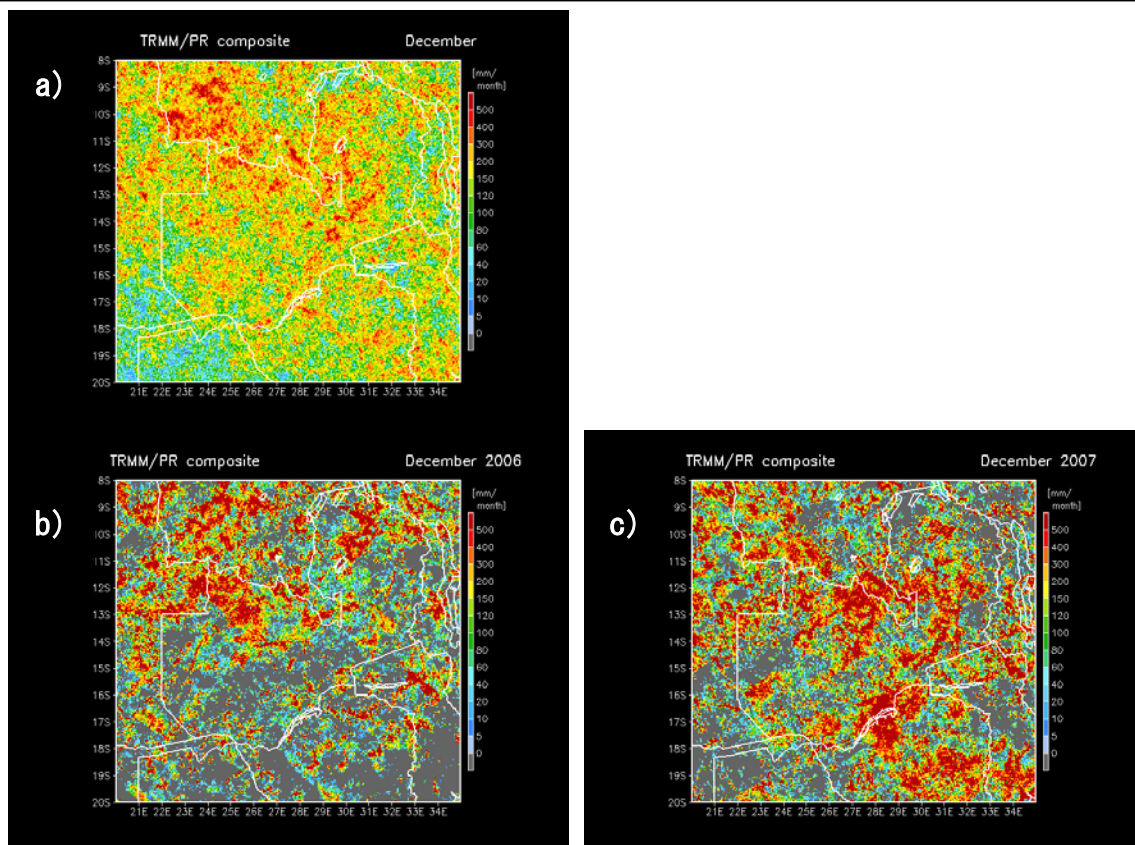
Figure 5. December rainfall climatology data from (a) TRMM/PR (same as that in Fig. 2c) and composite data for rainfall in (b) December 2006 and (c) December 2007.

4. Summary of rainfall patterns in Zambia

- ◉ Seasonal precipitation at Lusaka is decreasing, at least from the 1970s to 1990s.
- ◉ Seasonal precipitation at Chipato and Livingstone decreased from 1961 to 2003.
- ◉ Seasonal precipitation began to increase after 2003.
- ◉ Choma, Lusaka, and Livingstone receive less rainfall in El Nino years and more rainfall in La Nina years.
- ◉ Rainfall maxima around Lake Kariba were observed by TRMM/PR in December 2007.
- ◉ It is likely that ENSO (El Nino Southern Oscillation) is one of the most important factors regulating rainfall in South Zambia. However, other factors also should be investigated.

References

Saeki T., 2008: Sub-Theme IV-1: Global monitoring on the environmental change –
　　　Meteorological observations in Southern Province of Zambia. Vulnerability and
　　　resilience of social-ecological systems, FY2007 FY1 project report, Project 1-3FR
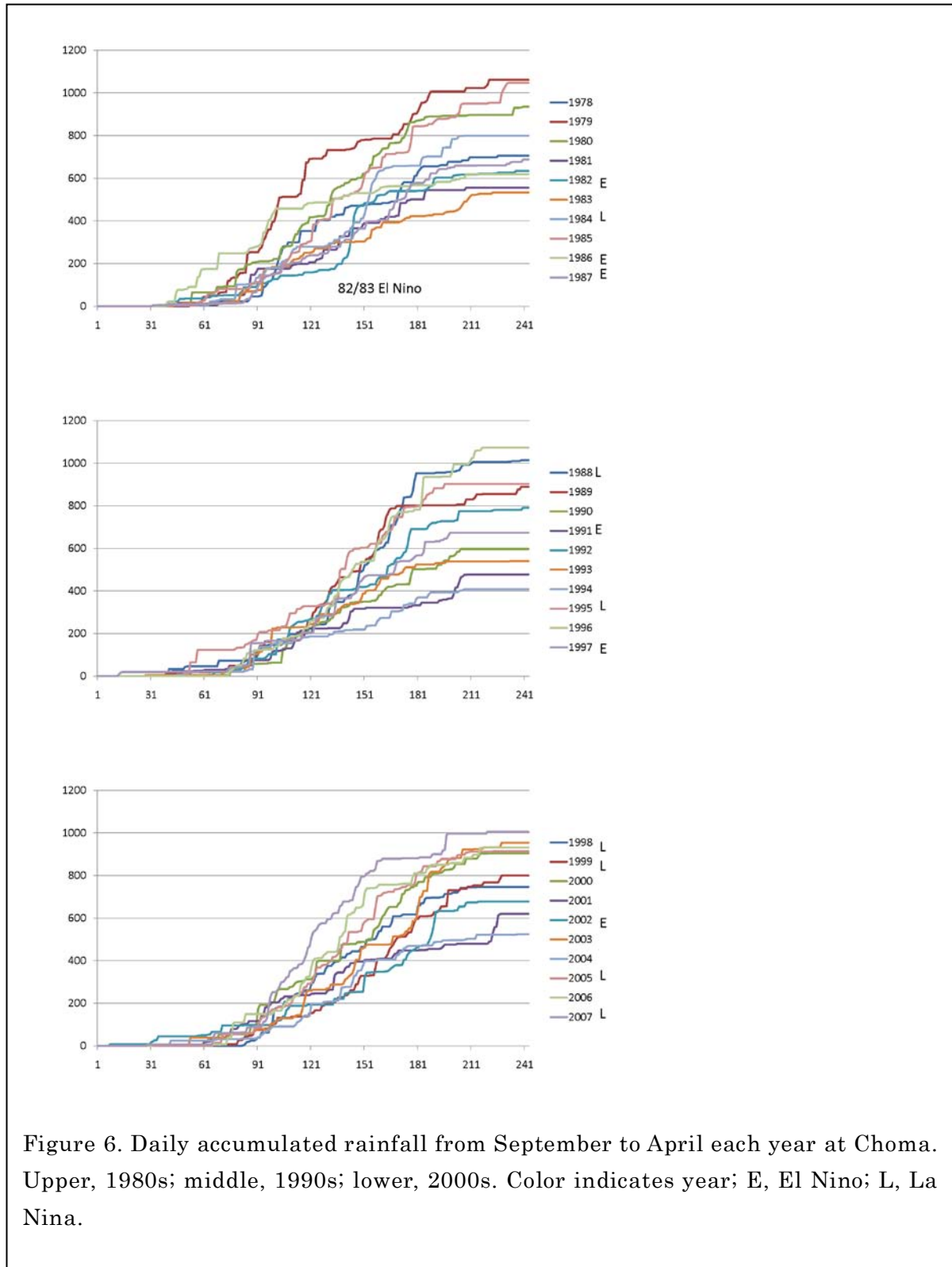　　　Research Insitute for Humanity and Nature, 99-104.

Figure 6. Daily accumulated rainfall from September to April each year at Choma.
Upper, 1980s; middle, 1990s; lower, 2000s. Color indicates year; E, El Nino; L, La
Nina.