Analysis of Meteorological Measurements Made over the 2008/2009 Rainy Season in Sinazongwe District, Zambia

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1. Introduction: Meteorological observation in 2008/2009

Local meteorological observations have been made in the Sinazongwe District, Zambia, from September 2007. A detailed analysis and results from the 2007/08 rainy season were reported in Kanno and Saeki (2009). In this paper, we summarize the characteristics of the 2008/09 rainy season and compare to the 2007/08 rainy season.

Two meteorological observation stations (weather stations) were installed at Siachaya Village (site C; high elevation, 1090 m) and Sianemba Village (site A; low elevation, 515 m). The stations were powered by a solar-charged battery and installed in a wide open area devoid of vegetation in the center of each village. Observations began in mid November 2008. Meteorological observations of air temperature, air pressure, relative humidity, solar radiation, precipitation, wind direction and wind speed were made at 30-min intervals and stored by a data logger. Wind direction was recorded as instantaneous values, whilst the other meteorological elements were recorded as mean values over a 30-min period (the 30 min prior to the time of data logging). Equivalent potential temperature (θe) and absolute humidity were calculated from air temperature, relative humidity and air pressure.

Separate to the observation stations mentioned above, a total of 48 rain gauges were installed at sites A and C as well as an additional location in Kanego and Chanzika villages (Site B; mid elevation, 720-986m) with 16 gauges at each site. Precipitation data was recorded at 30 min intervals and automatically stored in the data logger, from this data we have calculated hourly and daily precipitation means.

In this season, the condition of the rain gauges was generally poor, especially at site A. Some data loggers were broken by water overflow and other data loggers recorded zero at a period after the middle of rainy season (the cause being the rain gauge's water hole being clogged by mud). Consequently, the number of rain gauges with data which we can use was; 4 at site A, 6 at site B, and 9 at site C. At each station three rain gauges that did not experience any problems were used to form the mean precipitation data as outlined above.

2. Temporal variation of precipitation at each site

Precipitation data (recorded by the weather stations) for the two rainy seasons, 2007/08 and 2008/09, were compared for sites A and C. Figure 1 shows the accumulated daily precipitation at the two weather stations. At site A differences between the 2007/08 and 2008-09 rainy seasons were large; the total rainfall for the 2007/08 season was 1400 mm compared to 1053 mm in 2008/09, giving a difference of 247 mm. On the other hand, site C shows a small difference of 28 mm between the two rainy seasons (total rainfall at site C was 1272 mm in the 2007/08 rainy season and 1244 mm in 2008/09). This indicates that the precipitation in the high land (site C) is stable, but in the low-land (site A) precipitation tends to have a large year to year variation.

At site A the total amount of precipitation from November 1 to April 30 for the 2007/08 rainy season was 1575 mm compared to 1334 mm for the 2008/09 season (data from the separate rain gauge measurements). The rate of increase was almost constant in the 2008/09 rainy season (as shown by fig. 2), however an abrupt rise in the rate of increase (caused by heavy rain around late December) was seen in December for the 2007/08 season. The difference between the two rainy seasons was 241 mm, which is comparable to that derived from the weather station data (Fig. 1).

The total amount of precipitation at site B was 1586 mm in the 2007/08 rainy season compared to 1399 mm in 2008/09 (Fig. 3). Variations over time for both rainy seasons were similar to those from site A; the difference between the seasons is 197 mm, a little lower than at site A.

At site C the total amount of precipitation was 1401 mm in the 2007/08 rainy season compared to 1363 mm in the 2008/09 season (Fig. 4). The difference between the two rainy seasons was 38 mm, the smallest difference over the three sites.

When looking at the hourly precipitation (Fig. 5) distinct diurnal variations are present, with high precipitation between 2300 and 0100 hours at all sites (excluding the 2007/08 season at site B). At site C, a distinct diurnal variation was not clearly present for the 2007/08 season. The difference between the two rainy seasons was found to occur around the afternoon time; that is, in 2007/08 precipitation of around 50 mm/hour was observed from 1200 to 1700 hours, but in 2008/09 precipitation was low during that same period. It seems that the difference in total precipitation between the two rainy seasons was produced by heavy afternoon rainfall in the 2007/08 season. Since rainfall in the afternoon is frequently induced by unstable stratification, the difference in air stratification between two the rainy seasons might be an important factor in producing the different precipitation patterns seen here.

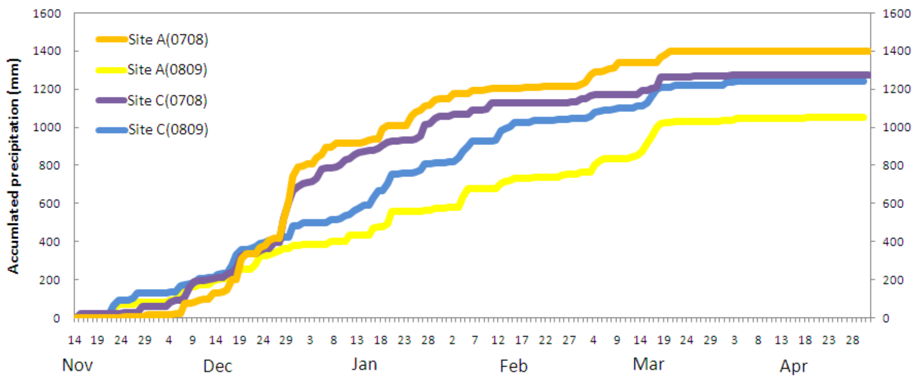

Fig.1: Daily accumulated precipitation (mm) at sites A and C from November 14 to April 30 for the two rainy seasons (2007/08 and 2008/09). Data were observed by meteorological weather stations.

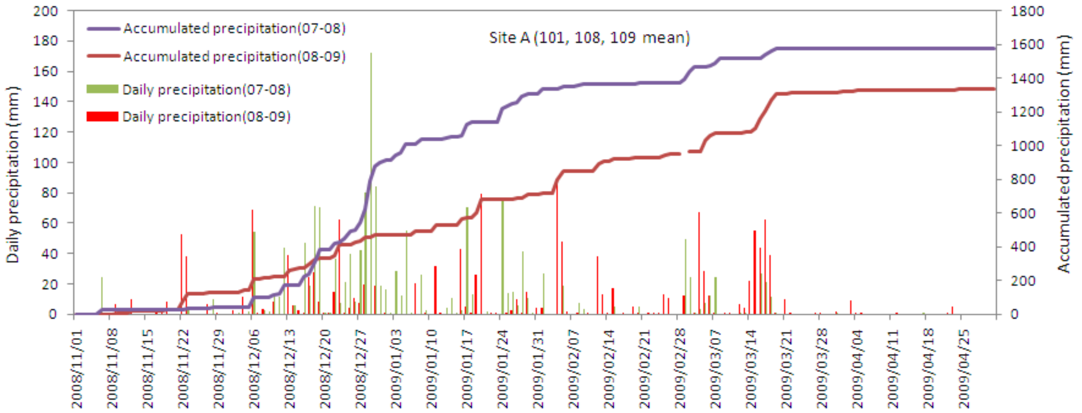

Fig. 2: Daily mean and accumulated precipitation (mm) at site A from November 1 to April 30 for the two rainy seasons (2007/08 and 2008/09). Precipitation was averaged over 3 data points for each station.

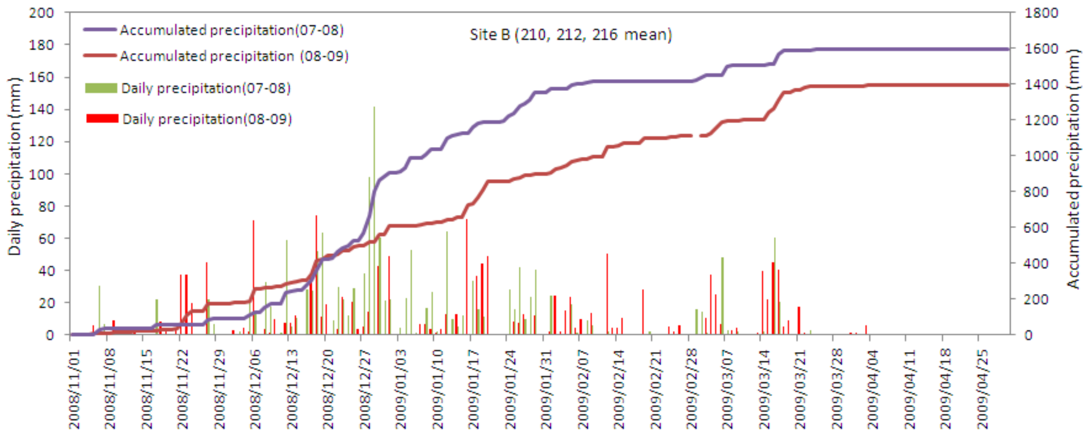

Fig. 3: As in Fig. 2 except for site B.

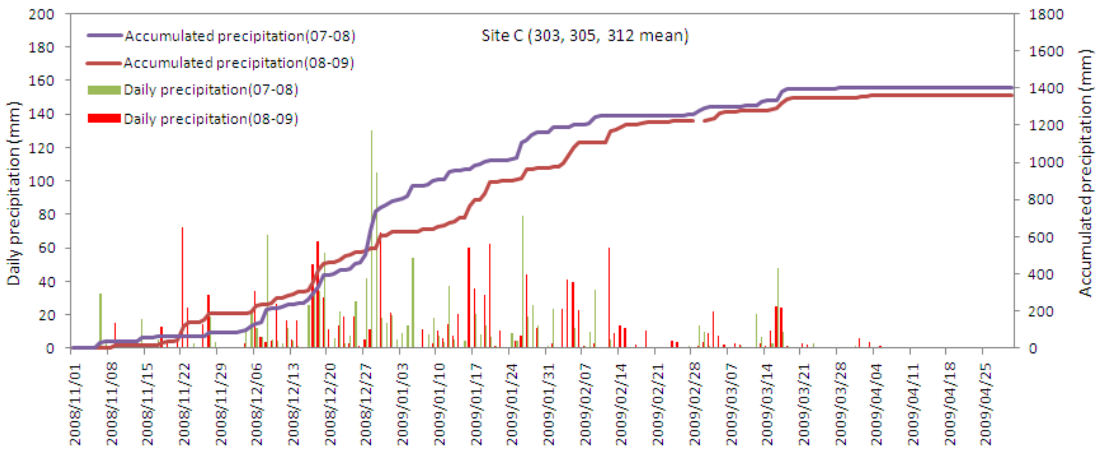

Fig. 4: As in Fig. 2 except for site C.

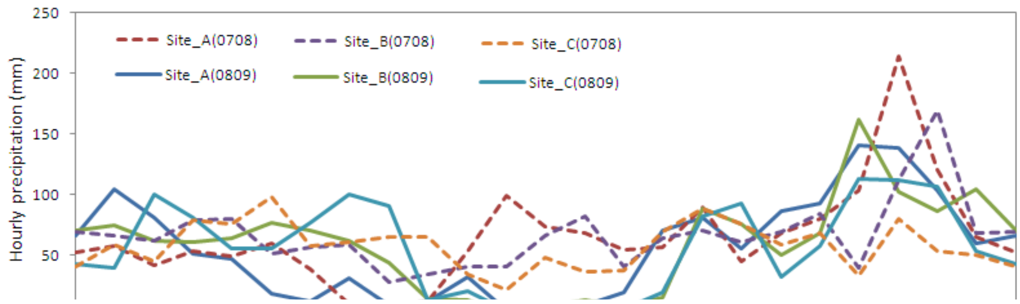

Fig. 5: Hourly precipitation (mm) from November 1 to April 30 for the two rainy seasons (2007/08 and 2008/09) at sites A, B and C.

3. Meteorological observation station data

In this section, daily and hourly variations of the meteorological parameters other than precipitation at sites A and C are discussed.

1) Temperature

At site C, during the 2008/09 rainy season from November to March, the daily mean temperature was around 20-23 °C and the daily temperature range was around 5-10 °C (Fig. 6). From the end of the rainy season in March minimum temperatures began to drop, the daily temperature range increased simultaneously. The maximum temperature stayed over 25 °C until June at which time it then dropped, sometimes lower than 20 °C, until the end of July. At site A, the temporal variations in temperature were similar but with values about 3 °C higher than at site C (Fig.7). The maximum temperature occasionally reached around 35 °C in the beginning of the rainy season and again in September.

Figure 8 shows the lapse rate of daily mean temperatures between sites C and A. The temperature lapse rate was calculated by using the height difference between the sites (1090 m at site C minus 515 m at site A = 575 m). In the 2008/09 rainy season the lapse rate was around 0.6 °C, after the rainy season the lapse rate decreased to around 0.5 °C or lower. This is lower than the moist adiabatic lapse rate (0.5 °C), implying that after the rainy season stratification may be stable. In comparison, the lapse rate for the 2007/08 rainy season was around 0.8 °C, larger than that for the 2008/09 season. This suggests that in the 2007/08 rainy season stratification might have produced unstable conditions through the rainy season and may possibly have given rise to the larger amount of precipitation than in 2008/09.

2) Wind speed

Both the 2007/08 and 2008/09 seasons show increased wind speed at site C in the early rainy season (Fig. 9). Wind speed then stabilized to around 1.0-1.5 m/s during the main period of the rainy season (December to March). By contrast, wind speed was weak (lower than 1.0 m/s) from December to March at site A in 2008/09. Looking at the variations over time between the two rainy seasons, site C shows a similar variation between the two years but there is a difference at site A. Given this difference in wind speeds and the fact that the amount of precipitation at site A varied between the two rainy seasons, it is possible that the synoptic conditions were also different.

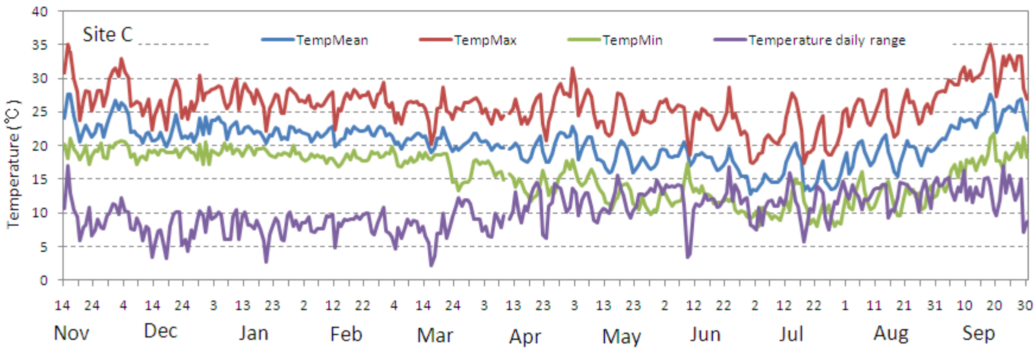

Fig. 6: Time series of maximum, average and minimum temperatures (°C) and the daily temperature range at site C from November 14 2008 to September 30 2009.

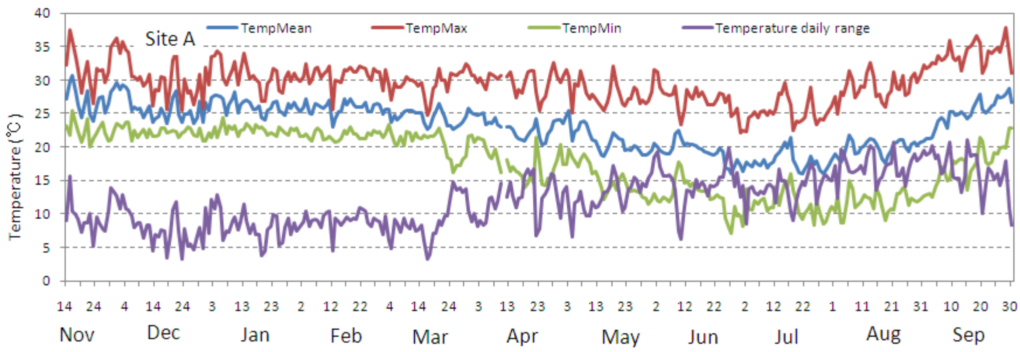

Fig. 7: As in Fig. 6 except for site A.

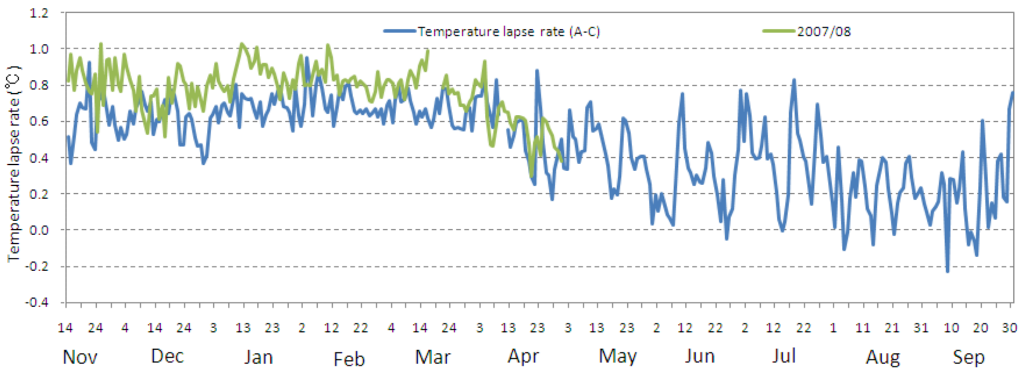

Fig. 8: Daily mean temperature lapse rate (°C/100 m) between sites A and C for the two seasons (2007/08 and 2008/09).

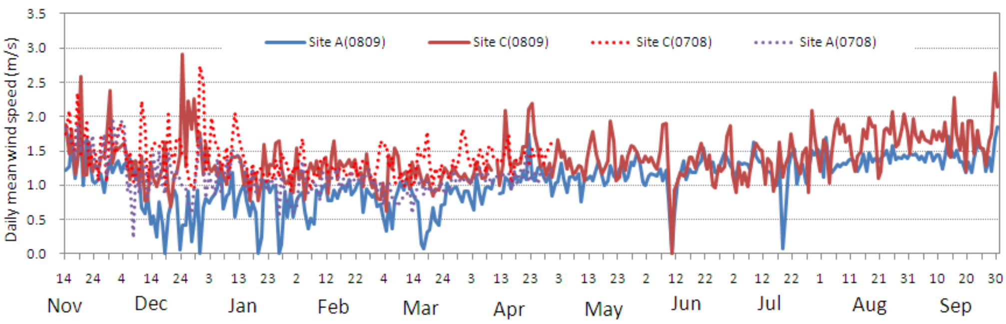

Fig. 9: Daily mean wind speed (ms^{-1}) at sites A and C for two seasons (2007/08 and 2008/09).

3) Solar radiation

The variation in daily solar radiation over time between the two sites was similar from rainy to dry seasons, but in the rainy season some differences between 2007/08 and 2008/09 were found (Fig. 10). Around late December to early January, the difference between the two rainy seasons is distinct; in 2007/08 solar radiation dropped to around 10-15 MJ/day, but in 2008/09 the value reached approximately 30 MJ/day. Since in this period precipitation also showed a difference between the two rainy seasons, it might be that a distinct synoptic system stagnated over the study area and produced heavy rainfall in the 2007/08 rainy season. On the other hand, around March, the two sites show similar variations over time for the two years, this possibly indicates that the frontal zone had moved from south to north by this time and that this occurrence may be fixed to this time every year.

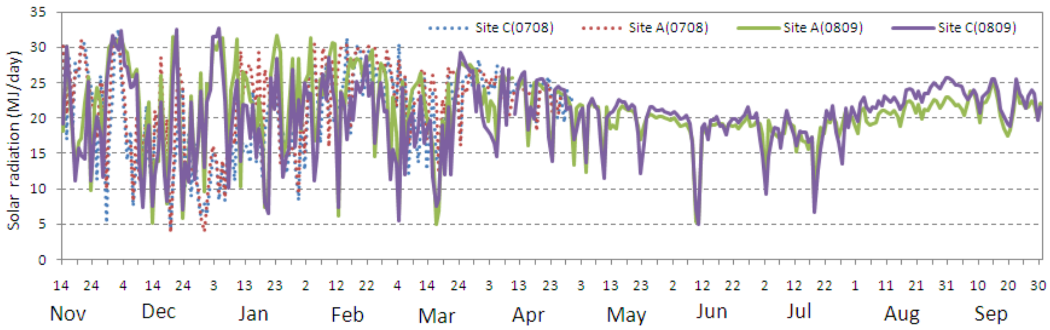

Fig. 10: Time series of daily solar radiation (MJ) at sites A and C for two seasons (2007/08 and 2008/09).

4) Humidity

For both sites A and C, during the 2008/09 rainy season, relative humidity was about 80-90% and then around late March it abruptly dropped (Fig. 11). This implies that the air mass alternated around this time. After this change, humidity gradually decreased until the dry season (around September) when it reached the least value of around 30-40%.

The mixing ratio was larger at site A than at site C (Fig. 12) due to the elevation difference. During the rainy season, the mixing ratio was around 15-20 g kg^{-1} but then dropped abruptly around late March. Since the continuous rainfall simultaneously ended at this time and the solar radiation rose (Fig. 10), it is clear that the air masses changed and was accompanied by frontal zone movement.

5) Equivalent potential temperature

The equivalent potential temperature (θe) shows a similar seasonal change to that of the mixing ratio (Fig. 13). Since θe gives a good indication of the air-mass characteristics and stratification taking into account the moisture content of the air, the difference between site A and C is also shown in Fig.13 (green line). During the rainy season, the difference was positive but from after April onward the difference varied from zero to negative, thus implying that the stratification in the rainy season was unstable and that after the last rainfall of the rainy season it maintained a stable condition.

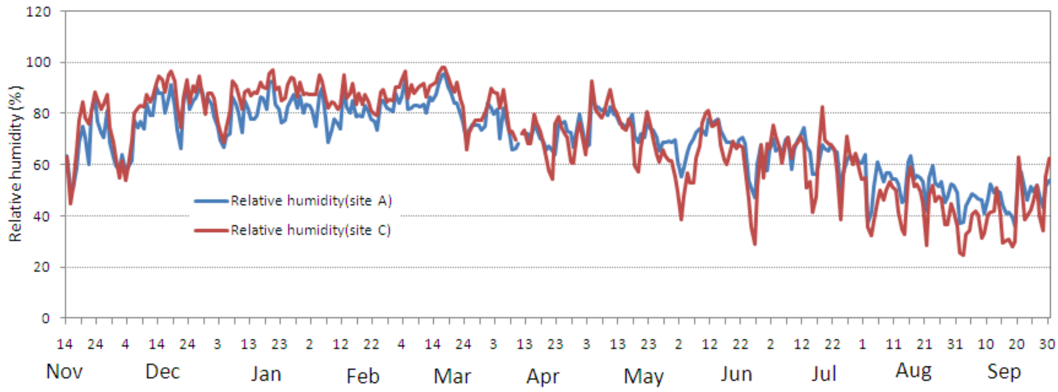

Fig. 11: Time series of relative humidity (%) at sites A and C from November 14 2008 to September 30 2009.

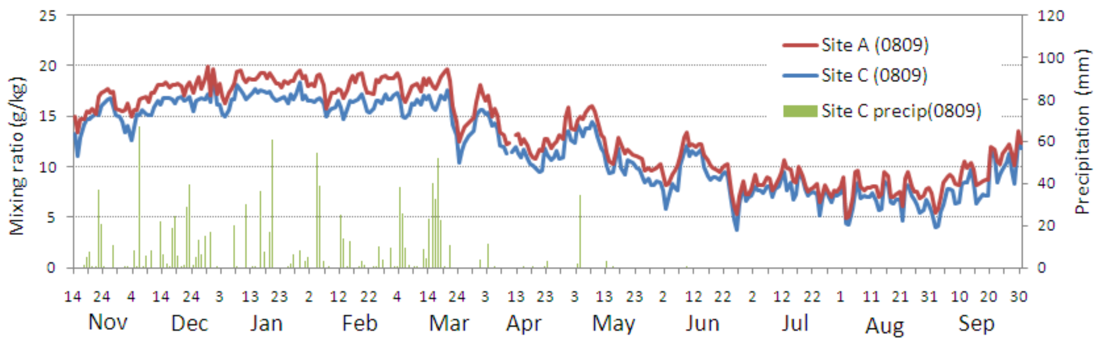

Fig. 12: Time series of mixing ratio (g kg^{-1}) at sites A and C, and daily precipitation at site C from November 14 2008 to September 30 2009.

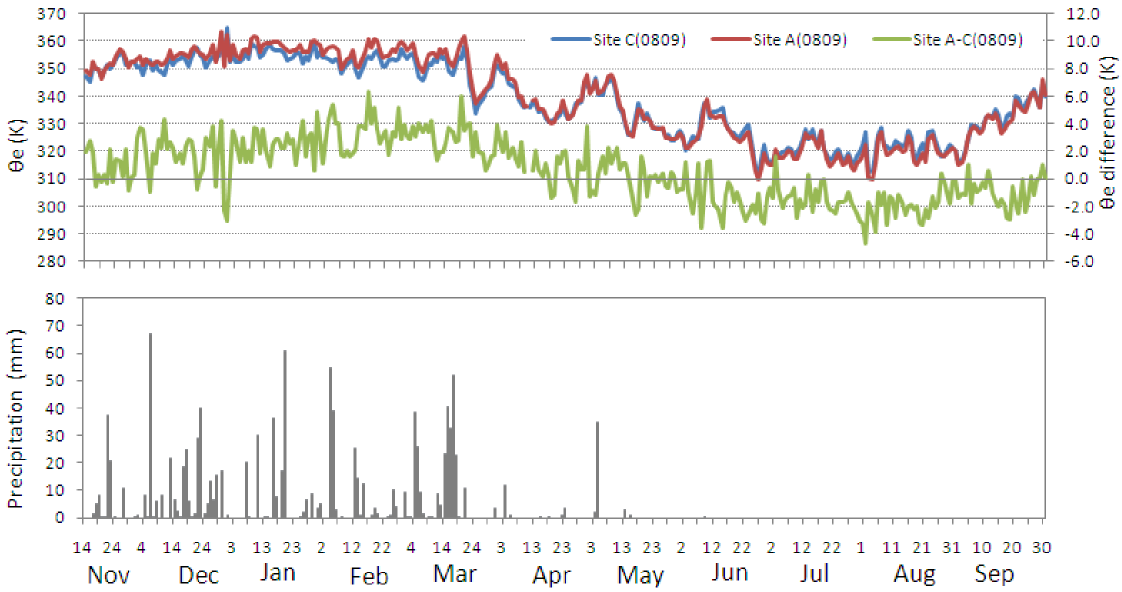

Fig. 13: Time series of equivalent potential temperature θe (K), the difference in equivalent potential temperature θe between sites A and C (as shown by green line) and daily precipitation at site C from November 14 2008 to September 30 2009.

4. Conclusions

Local meteorological observations were made at three research sites in the Sinazongwe District, Zambia from September 2007 onward. The observation data were analyzed and compared over two rainy seasons, 2007/08 and 2008/09. The results are summarized as follows:

1. Amounts of precipitation over the two rainy seasons, 2007/08 and 2008/09, show that the differences between the two rainy seasons were large at site A but small at site C. This indicates that the precipitation in the high land (site C) is stable, but tends to have a large year to year variation in the low-land (site A).

2. Hourly accumulated precipitation showed distinct diurnal variations with high precipitation between 2300 and 0100 hours at all sites (excluding the 2007/08 rainy season at site B). Since the difference between the two rainy seasons was found to occur around the afternoon time, it seems that the difference in the total amount of precipitation between the two rainy seasons was produced by the heavy afternoon rainfall in the 2007/08 season.

3. Temporal variations in temperature at sites A and C show a similar pattern, however at site A the values were higher than at site C. The lapse rate of daily mean temperatures between sites A and C showed that the lapse rate in the 2007/08 rainy season was larger than in the 2008/09 season. This suggests that throughout the 2007/08 rainy season, stratification was unstable and possibly induced the larger amount of precipitation in comparison to 2008/09.

4. Wind speed differences between the two rainy seasons were large at site A but small at site C. Given this difference and that the precipitation amount at site A varied between the two rainy seasons, it is possible that synoptic conditions were also different.

5. The daily solar radiation around late December to early January indicates a large difference between the two rainy seasons. Since in this period precipitation was also different, it may be that a distinct synoptic system stagnated and produced heavy rainfall in the 2007/08 rainy season. Also, around March for both seasons there are similar variations in solar radiation, this possibly indicates that the frontal zone had moved from south to north by this time and that this is a yearly occurrence.

6. The relative and absolute humidity might indicate that the air masses alternated and were accompanied by frontal zone movement around late March. The temporal variation of equivalent potential temperature (θe) implies that the stratification in the rainy season was unstable and that after the last continuous rainfall a stable condition was maintained.

Reference

Kanno, H. and Saeki, T., 2009: Analysis of meteorological measurements made over the rainy season 2007/2008 in Sinazongwe District, Zambia. FY2008 FR2 Project Report, Research Institute for Humanity and Nature, 50-65.