Precipitation Trends in Western Uganda

Greg DiSanto
B.A. Geography, University of New Hampshire

Advisors:
Joel Hartter & Mary Stampone
Department of Geography
University of New Hampshire

University of New Hampshire
Hamel Center for Undergraduate Research

Background

The Albertine Rift in East Africa (Fig. 1) is a densely populated area with a rapidly growing population. Many people in the region are farmers whose livelihoods depend on rain-fed agriculture and locally-derived natural resources. This makes them very sensitive to variability in the amount and timing of seasonal rainfall. In Western Uganda, there are two rainy seasons and two dry seasons (Fig. 3, left). Any changes in the timing of rainfall can impact crop productivity (Naylor et al. 2007). Analyzing precipitation data from Western Uganda for trends in the timing of the rainy season can help farmers adapt to any changes in the precipitation regime.

Insert Map

Figure 1: Map of Uganda. Green areas represent national parks. Dots represent the 56 precipitation stations used in this study.

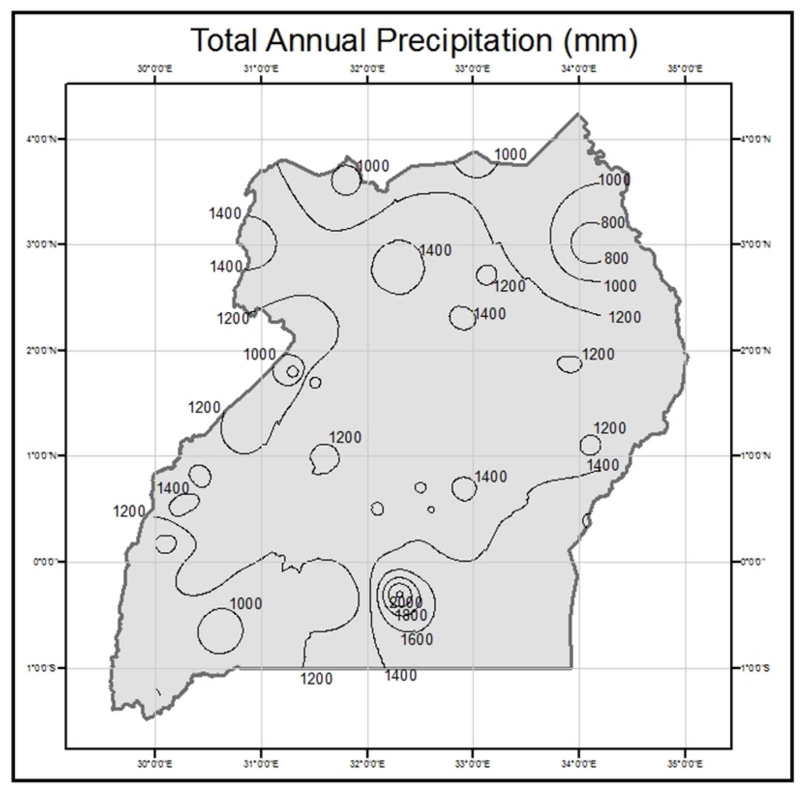

Figure 2: Distribution of mean annual precipitation in Uganda. Annual precipitation is approximately 1300 mm throughout the country.

Objectives

This study seeks to answer the following questions:

1. Does precipitation and the timing of the rainy season vary by location?
2. Is the timing of the rainy season changing over time? If so, where is it changing?

Works Cited

Naylor R.L., Battisti D.S., Vimont D.J., Falcon W.P., Burke M.B. 2007 Assessing risks of climate variability and climate change for Indonesian rice agriculture. *P. Natl. Acad. Sci. USA* 104: 7752–7757.
Horn, L. and Bryson, R.A. 1960. Harmonic analysis of the annual march of precipitation over the United States. *Ann. Assoc. Amer. Geogr* 50(2): 157-171.

Acknowledgements

This project was funded by a the Hamel Center for Undergraduate Research at the University of New Hampshire.
Monthly and daily precipitation data was measured by countless people in Uganda, and the data was collected for me by Joel Hartter (UNH) and Jeremy Diem (Georgia State University).

Methods

Daily precipitation records date back to 1976 at some stations and monthly total precipitation data go back as far as 1896, although most stations' monthly data does not go back farther than the 1940s.

For each year at each station, harmonic analysis will be performed on monthly total precipitation data to fit a curve to the annual precipitation data. This curve, computed in MATLAB, is the sum of six simple cosine waves with frequencies of 1 year^{-1} to 6 year^{-1} (Fig. 3). Horn and Bryson (1960) showed six frequencies are sufficient to explain the variability in a station's precipitation. The amplitude, phase shift, and vertical shift of each wave are used for analyzing trends in precipitation.

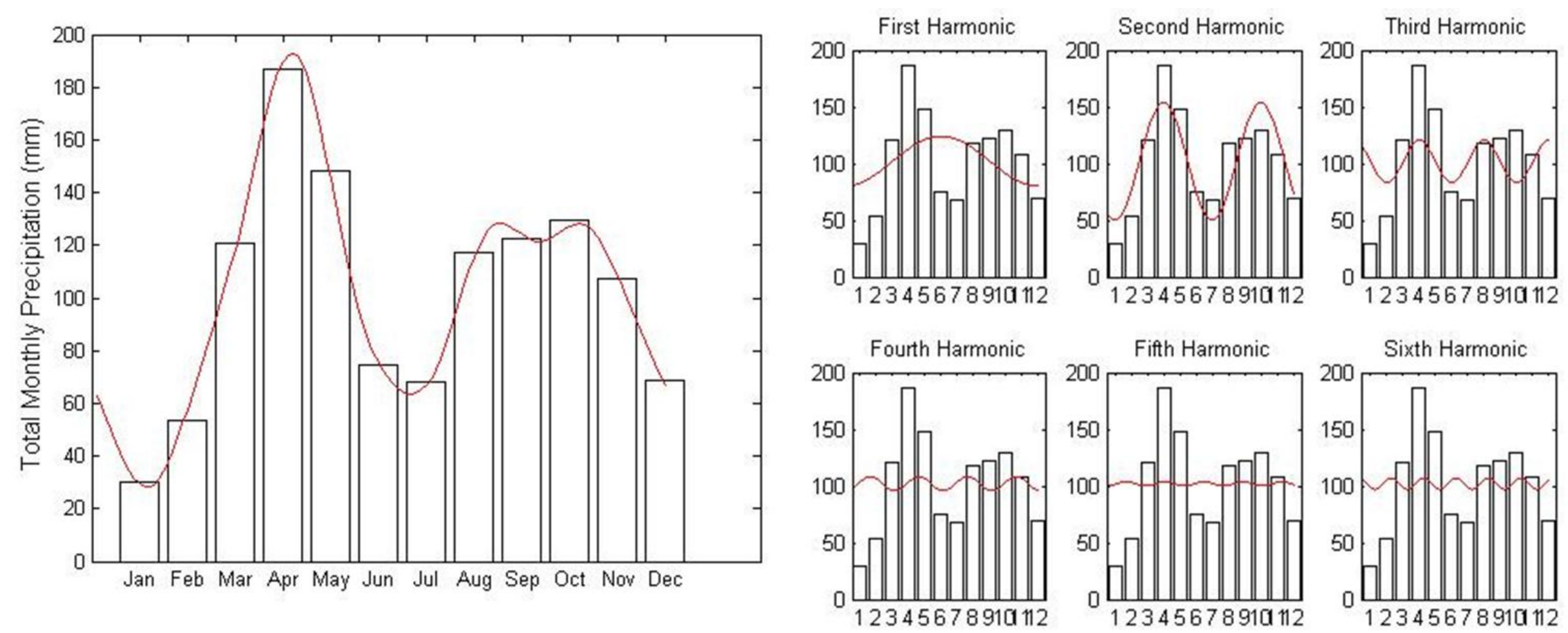

Figure 3 (left): Mean monthly precipitation data at the Namasagali/B. Gombolo station with best fit curve, the sum of of six simple cosine waves with frequencies of 1 year^{-1} to 6 year^{-1}.
Figure 3 (right): Six cosine waves with frequencies of 1 year^{-1} to 6 year^{-1} fitted to mean monthly precipitation data at the Namasagali/B. Gombolo station.

Trend Analysis

The amplitude, phase shift, and vertical shift of each wave are used for analyzing trends in precipitation.
The percentage of month-to-month precipitation explained by a harmonic can be determined dividing the square of the amplitude of that harmonic by the sum of the squares of all six harmonics.
Whether a station's variation in precipitation can be explained mostly by biannual processes or annual processes can be expressed by the ratio of the amplitude of the second harmonic to the amplitude of the first harmonic (A_2/A_1).
Whether a a station's variation in precipitation can be explained mostly by large-scale or small-scale processes can be expressed by the ratio of the amplitudes of the first three harmonics to the amplitudes of the last three harmonics.

$$\frac{A_1 \times A_2 \times A_3}{A_4 \times A_5 \times A_6}$$

For most of Uganda, approximately 85% to 95% of variability in monthly precipitation obtained in first three harmonics.

Station	Long. (°E)	Lat (°N)	Elevation (m)	Annual Precip. (mm)	First Harmonic Amplitude (mm)	First Harmonic Phase (months)	Second Harmonic Amplitude (mm)	Second Harmonic Phase (months)
Arua	30.90	3.00	1280	1481.9	77.90	7.65	34.50	3.69
Bulisa	31.40	2.10	1036	1087.0	51.20	7.68	31.10	3.79
Gulu	32.30	2.80	1105	1531.3	80.90	7.14	37.50	3.85
Kitgum V.T.C.	32.80	3.30	937	1257.2	77.50	6.79	18.10	3.97
...	...	...	...	...	...	...	...	...

Table X: First four of 56 stations from which monthly precipitation data was collected.

Results

In Uganda, annual climatic processes appear to have the largest influence on monthly precipitation in the higher latitudes while biannual climatic processes appear to have the largest influence on monthly precipitation closer to the equator (Figure 3).
The phase of the first harmonic is closest to 6.75 months in higher latitudes (Figure 4). This means that more northerly latitudes tend to have a maximum amplitude of the first harmonic that occurs closer to the summer solstice. There appears to be higher spatial variability in phase of the first harmonic at lower latitudes.
For most of Uganda, the maximum amplitudes of the second harmonic occur around the spring and fall equinoxes.

Figure 3 (Left): Percentage of total variability in monthly precipitation explained by first harmonic.
Figure 3 (Middle): Percentage of total variability in monthly precipitation explained by second harmonic .
Figure 3 (Right): Ratio of the amplitude of the second harmonic to the amplitude of the first harmonic. Numbers greater than zero represent areas where a higher proportion of monthly variability is caused by biannual climatic processes than annual processes.

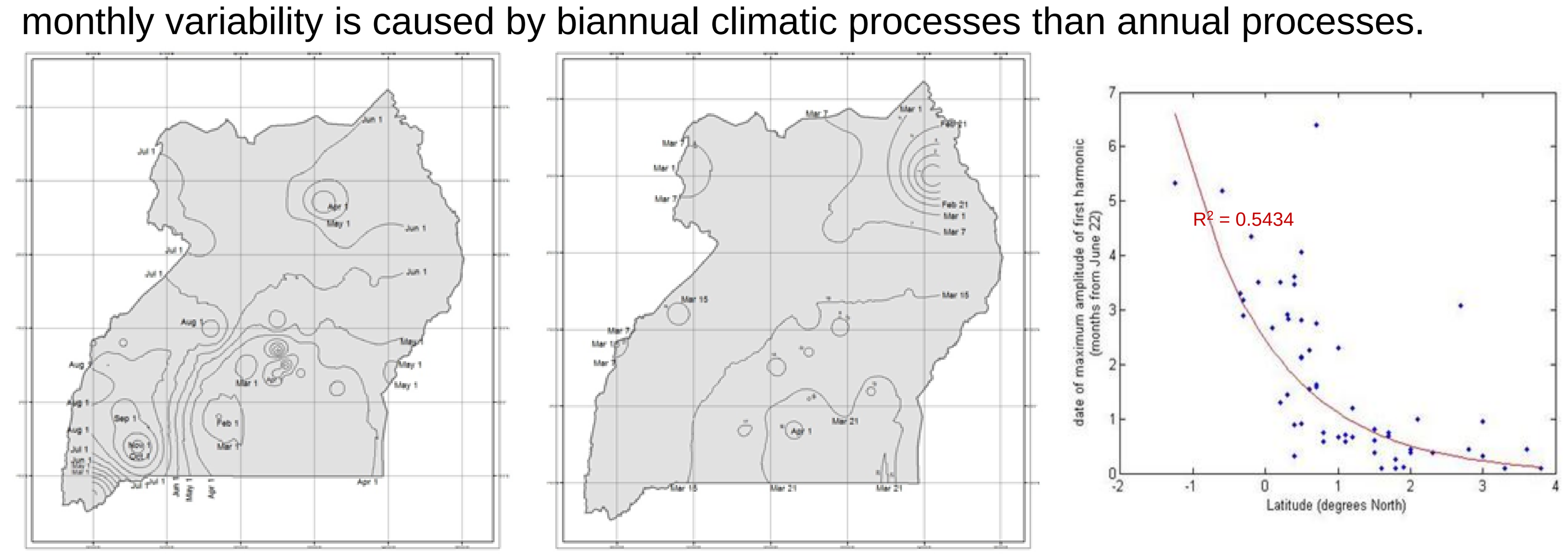

Figure 4 (Left): Dates of the maxima of the first harmonic. In areas where the date of the maximum of the first harmonic occurs in the spring, the first rainy season is the wettest. In areas where this occurs in the fall, the second rainy season is the wettest. In areas where this occurs in the summer, the summer dry season is relatively wet.
Figure 4 (Middle): Spring dates of the maxima of the second harmonic. The second harmonic is also at a maximum six months later.
Figure 4 (Right): Date of maximum amplitude of the first harmonic as a function of latitude.

Conclusions

That the A_2/A_1 ratio is higher in the lower latitudes could be linked to the ITCZ.

The timing of annual climatic processes that control precipitation appear to vary by latitude in Uganda, but not by longitude or elevation. There appears some spatial variability in the timing of biannual climatic processes, which have a large influence on the timing of the two rainy seasons, but a finer spatial distribution of rainfall stations in Uganda would help determine just how great this variability is.