A Drying Trend in Central Equatorial Africa

Jeremy E. Diem
Department of Geosciences
http://geosciences.gsu.edu
jdiem@gsu.edu

Joel Hartter
Department of Geography
http://www.unh.edu/geography

Michael W. Palace
Institute for the Study of Earth, Oceans, and Space
http://www.eos.unh.edu

Sadie J. Ryan
Department of Environmental and Forest Biology
http://www.esf.edu/efb

CNH-Ex 1114977

Background: Central equatorial Africa has been in need of rainfall data. It is a region with no definitive ground-based information on long-term trends in rainfall, and modeling studies have shown that rainfall in the region should decrease not only from an increase in carbonaceous aerosols from biomass burning in tropical Africa but also from a warming of the equatorial Indian Ocean. On the eastern edge of the region is the Albertine Rift, a hotspot for biodiversity that also has some of Africa's fastest growing human populations, dependent almost entirely on rain-fed agriculture.

Purpose: The aim of this study to assess trends from 1983-2012 in rainfall in west-central Uganda and other portions of equatorial Africa using the recently completed African Rainfall Climatology Version 2 (ARC2) product. This satellite-based rainfall product extends back to 1983 and is expected to be homogeneous over time, and our previous research has shown ARC2 to be accurate at identifying rainfall days and estimating 90-day rainfall totals in west-central Uganda.

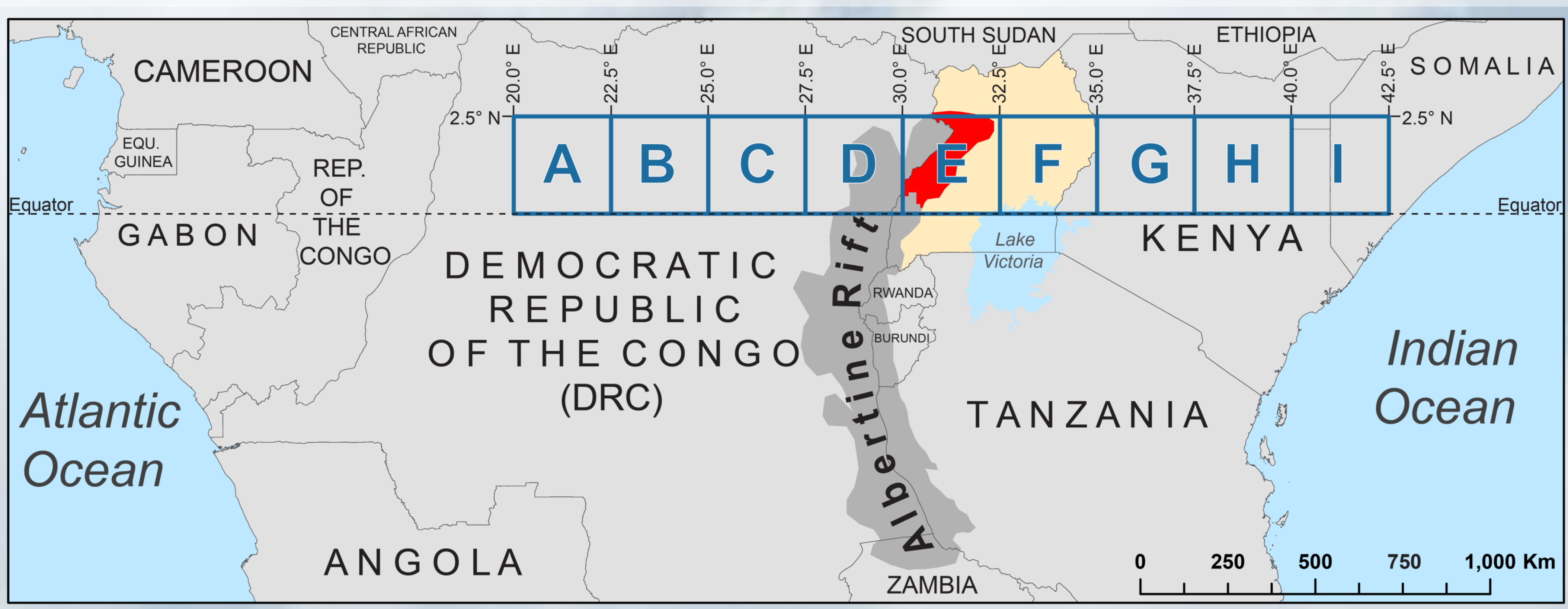

Fig. 1 Geographical location of west-central Uganda in tropical Africa. West-central Uganda (in red) is located in central equatorial Africa at the northern end of the Albertine Rift. Nearly the entire region exists within a 2.5° cell (E). Other analyses of rainfall are conducted within the boundaries other 2.5° cells (A-D and F-I) extending from northwestern Democratic Republic of the Congo to western Somalia.

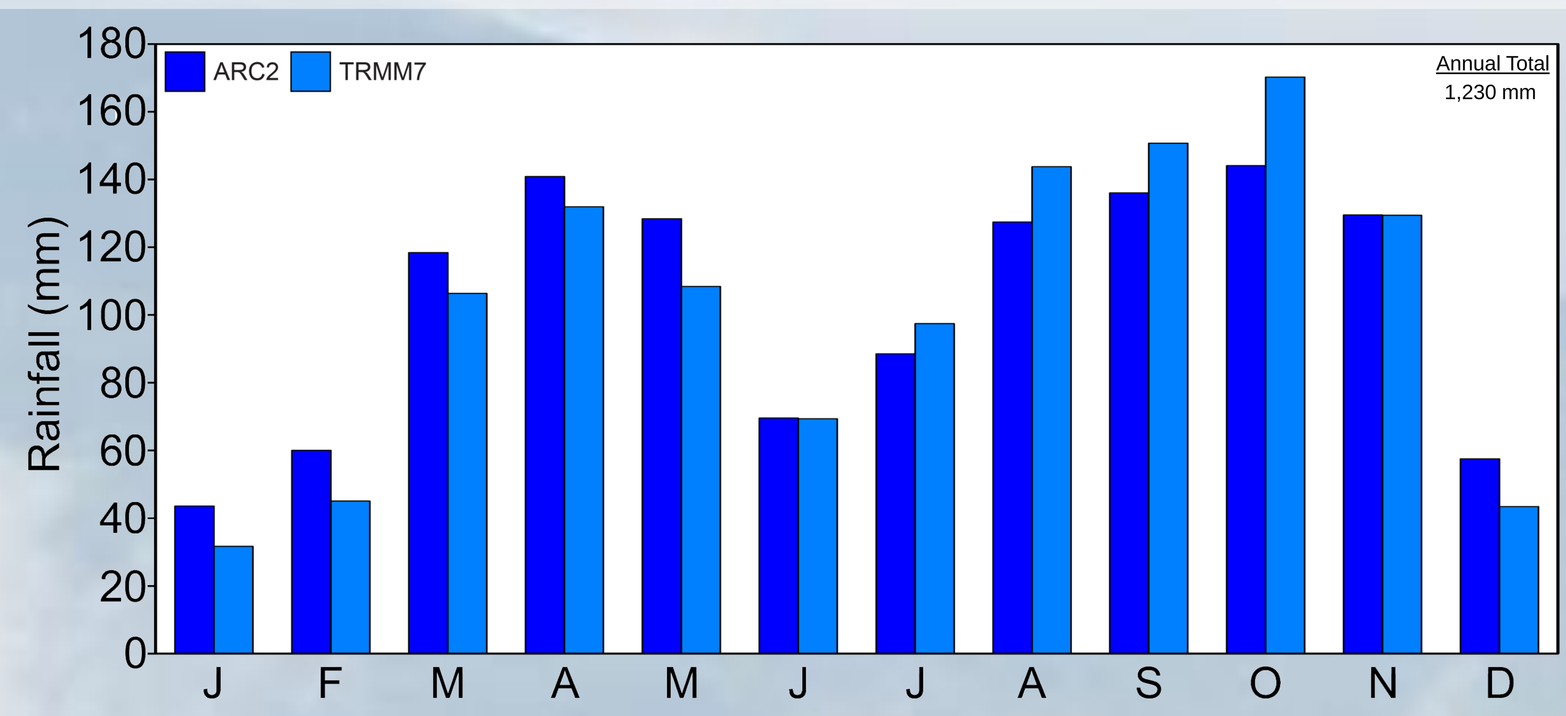

Fig. 2 Mean monthly rainfall totals in west-central Uganda from 1998-2012 derived from daily African Rainfall Climatology Version 2 (ARC2) and Tropical Rainfall Measuring Mission Version 7 (TRMM7) rainfall estimates.

- West-central Uganda and the rest of central equatorial Africa do not have a true dry season
- Boreal-summer rainfall is relatively high
- Peak rainfall occurs during the equinoctial seasons (e.g., ITCZ influence); there are two growing seasons
- Farmers typically plant in February and July/August

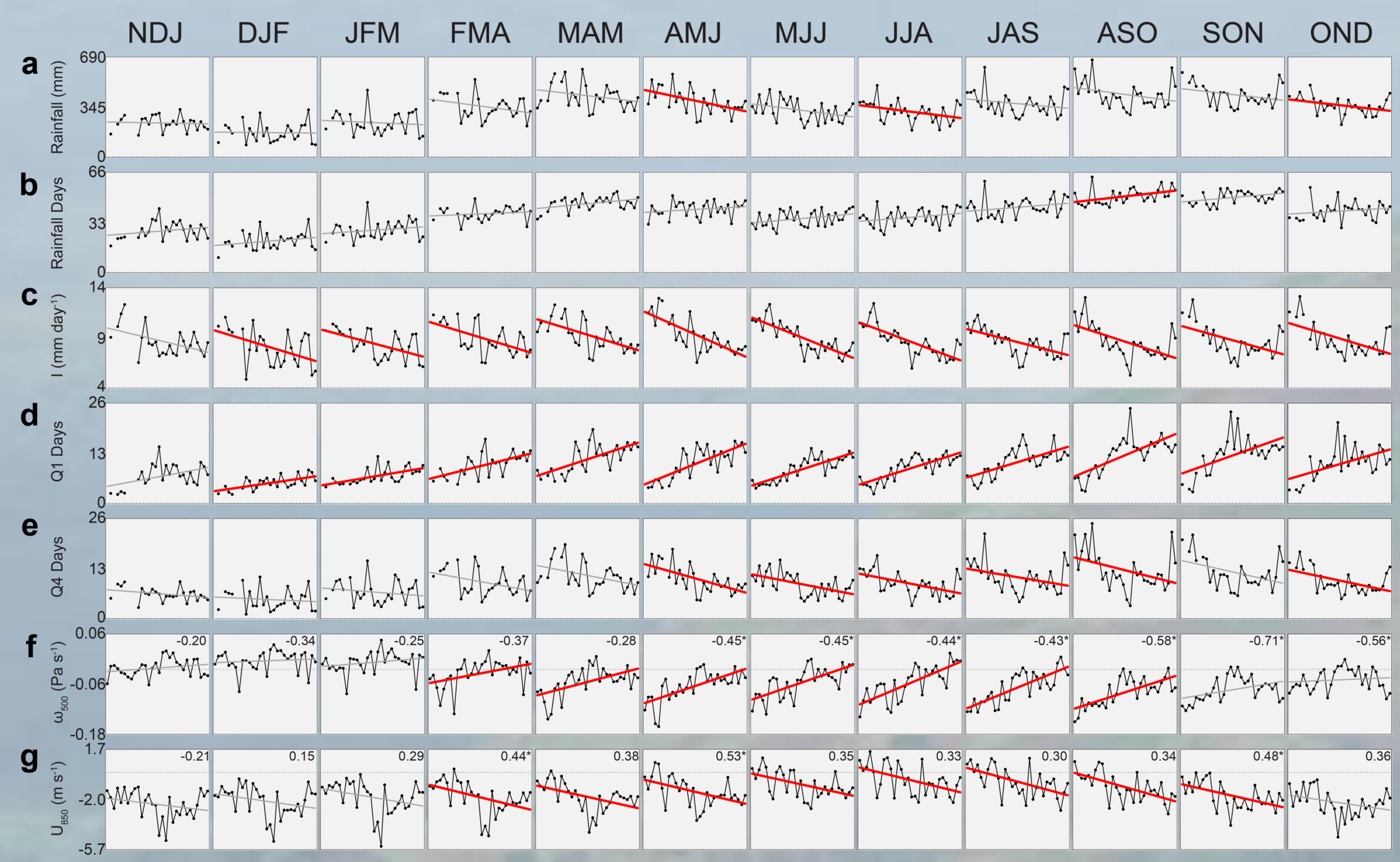

Fig. 3 Time series from 1983-2012 of rainfall and atmospheric variables over west-central Uganda for overlapping three-month periods. a, Rainfall totals. b, Rainfall days. c, Rainfall intensity (I) for rainfall days. d, First-quartile (Q1) rainfall days. e, Fourth-quartile (Q4) rainfall days. f, 500-hPa omega vertical motion (ω_{500}). g, 850-hPa zonal wind (U_{850}). Red lines indicate significant ($\alpha = 0.01$; one-tailed) trends and dashed lines indicate non-significant trends. The numbers in the ω_{500} and U_{850} panels are correlation coefficients between those variables and rainfall; asterisks denote significant ($\alpha = 0.01$; one-tailed) correlations.

- Decreasing rainfall from 1983-2012 in west-central Uganda is centered on boreal summer and coincided with changes in atmospheric circulation (e.g., possible westward expansion of the Walker circulation over the region)
  - Increased subsidence
  - Increased easterly flow and presumably less moisture flow from the Congo
- The frequency of rainfall days generally increased
- Nearly all three-month periods had an increase in light-rainfall days and a decrease in heavy-rainfall days
  - Shift towards lighter rainfall

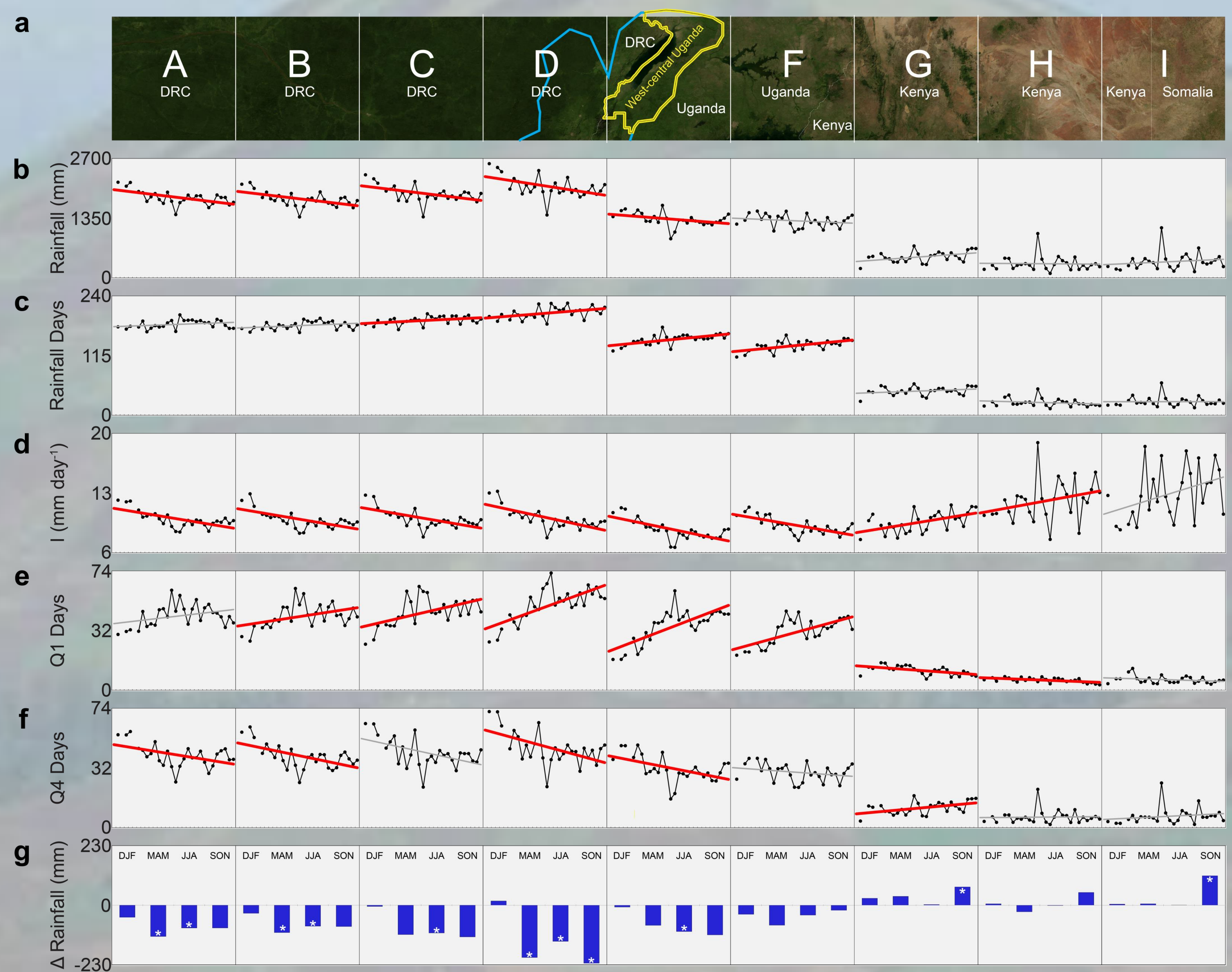

Fig. 4 Changes in annual and seasonal rainfall for west-central Uganda and eight cells (A-D and F-I). a, True-color April image of a portion of equatorial Africa obtained from the National Aeronautics and Space Administration's Blue Marble Next Generation dataset. The yellow polygon is west-central Uganda and the blue line shows the rest of the boundary of the Albertine Rift. Time series from 1983-2012 of b, annual rainfall, c, rainfall days, d, intensity (I) of rainfall days, e, first-quartile (Q1) days, and f, fourth-quartile (Q4) days. Red lines indicate significant ($\alpha = 0.01$; one-tailed) trends in annual values and grey lines indicate non-significant trends. g, Difference from 1983 to 2012 in seasonal rainfall totals. Asterisks indicate significant ($\alpha = 0.01$; one-tailed) trends in seasonal rainfall.

- The drying trend in west-central Uganda from 1983-2012 may have extended westward into the rainforest areas of the DRC and was nonexistent eastward in central Kenya and southern Somalia
- The drying trend in central equatorial Africa appears to have occurred in all seasons but boreal winter
- There is a reversal in trends in rainfall characteristics between central equatorial Africa and eastern equatorial Africa

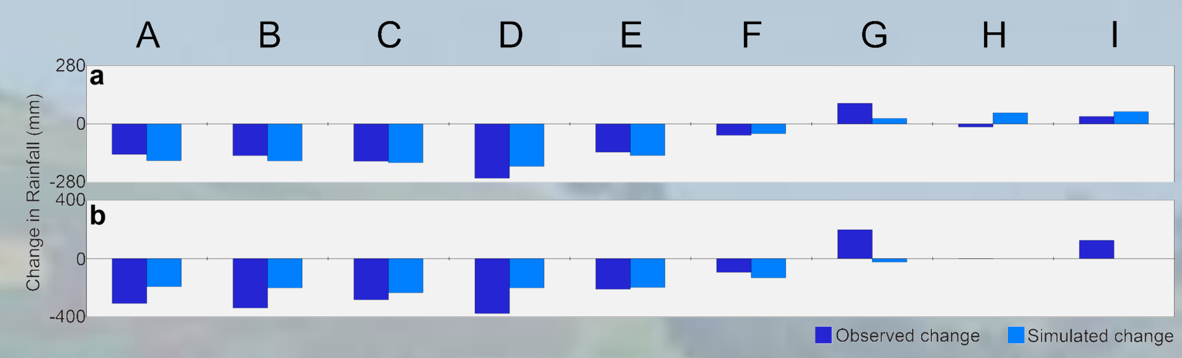

Fig. 5 Observed and simulated changes in rainfall in the nine cells (A-I). (a) Observed changes from 1983-2012 in cumulative February-April and July-September rainfall and simulated cumulative changes in rainfall over those six months resulting from a warming of the Indian Ocean, with a maximum warming of 1° C at the equator.[1] (b) Observed changes from 1983-2012 in annual rainfall and simulated changes in rainfall when moving from a scenario without landscape-fire aerosols to a scenario with those aerosols.[2]

- Either Indian Ocean warming or carbonaceous aerosols from biomass burning in tropical Africa – or both – are primarily responsible for the decreasing rainfall
  - A simulated increase in SSTs of the equatorial Indian Ocean decreases rainfall in central equatorial Africa[1]
    - The western equatorial Indian Ocean did warm from 1983-2012
  - A simulated increase in biomass burning and thus concentrations of carbonaceous aerosols also produces rainfall decreases in central equatorial Africa[2]
    - It is unknown if aerosol concentrations over tropical Africa have increased from 1983-2012

[1] Hoerling, M., J. Hurrell, J. Eischeid, and A. Phillips, 2006: Detection and attribution of twentieth-century northern and southern African rainfall change. *J. Clim.* 19, 3989-4008.
[2] Tosca, M.G., J.T. Randerson, and C.S. Zender, 2013: Global impact of smoke aerosols from landscape fires on climate and the Hadley circulation. *Atmos. Chem. Phys.*, 13, 5227-5241.

Conclusions

- Rainfall in west-central Uganda has been decreasing over the past three decades
- The drying trend is centered on boreal summer
- Annual rainfall in west-central Uganda decreased about 20% from 1983-2012
- There is evidence that anthropogenic activities have caused the drying trend in central equatorial Africa