Climate of the Congo Basin: the state of our understanding, challenges and opportunities

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Abstract

The Congo Basin stands out as a convective hotspot and plays a crucial role in the Earth's climate system by modulating the atmospheric circulation and carbon emissions caused by biomass burning in its southern and northern bands. Climate variability in this region is a result of interactions among various features acting on different time-scales. This presentation provides an overview of our current understanding of such features that operate at regional (e.g., Walker-like cells) and global (e.g., ENSO) scales. The distinct spatial heterogeneity of the region with respect to interannual variability will be presented and compared with the spatial variability of annual and diurnal cycles. Differences in driving factors of these variabilities will be discussed. Some challenges, such as the lack of in-situ observations, that limit the climate analysis over the region will be addressed. Finally, several aspects of future research opportunities will be highlighted. This includes interactions between local atmospheric jets, waves, precipitation-producing systems, deforestation and biomass burning, as well as potential improvements in collecting ground-based meteorological data in the region.

Climate of the Congo Basin: the state of our understanding, challenges and opportunities

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Most materials are borrowed from a recent review article written for *the Oxford Research Encyclopedia of Climate Science* (Dezfuli 2017).

What we know:

The Congo Basin stands out as a hotspot of convective systems and biomass burning. It has a distinct diurnal cycle and spatial heterogeneity of interannual variability and annual cycle of rainfall. Its moisture is supplied via advection from neighboring areas (lands or oceans) or from local recycling. It also supplies moisture to other parts of Africa. Its climate is modulated by several Walker-like cells and tropospheric jets, but also affects the global atmospheric circulation in transition months.

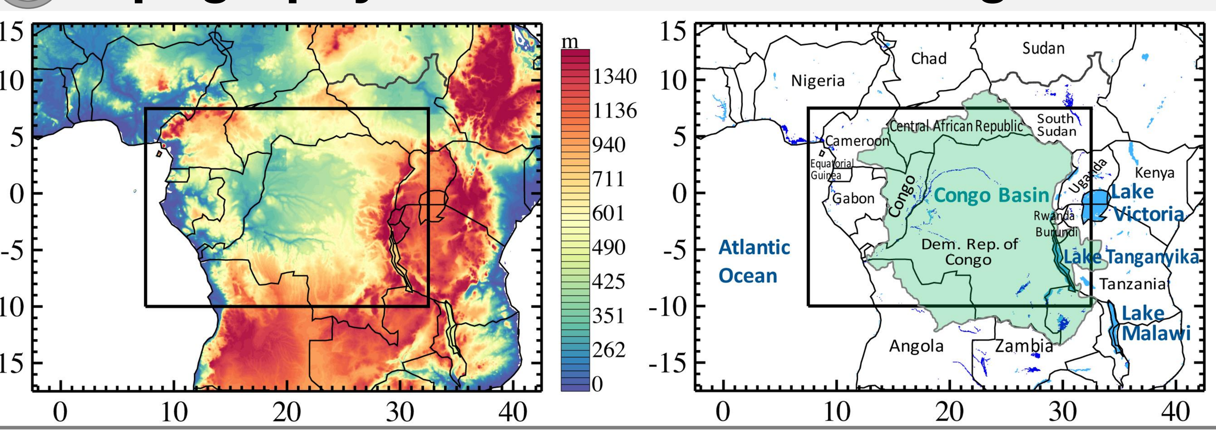
Challenges:

Lack of in-situ data; intrinsic complexity of the region's climate due to the wide range of spatiotemporal scales of the contributing phenomena and their interactions.

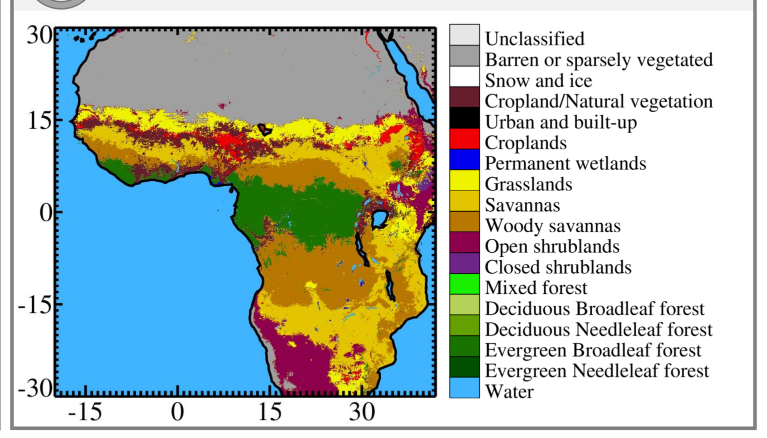
Future work:

May focus on better understanding of the characteristics of rainfall-producing systems (e.g., MCSs); local and remote impacts of deforestation and biomass burning; regional equatorial waves, Walker-like cells, and tropospheric jets. Recent advances in satellite observations and climate models have facilitated such studies.

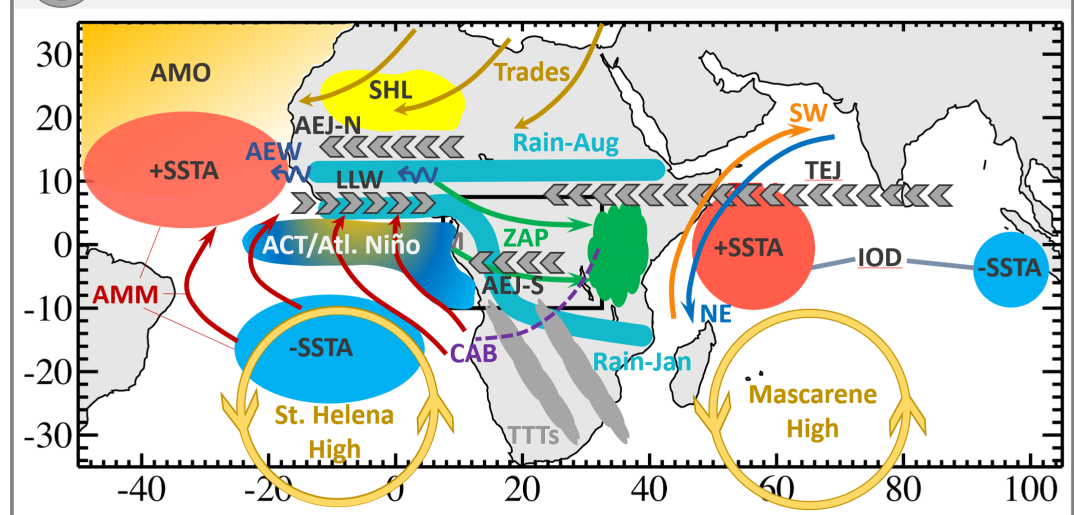
1 Topography & Location of the Congo Basin



2 Land Use/Land Cover

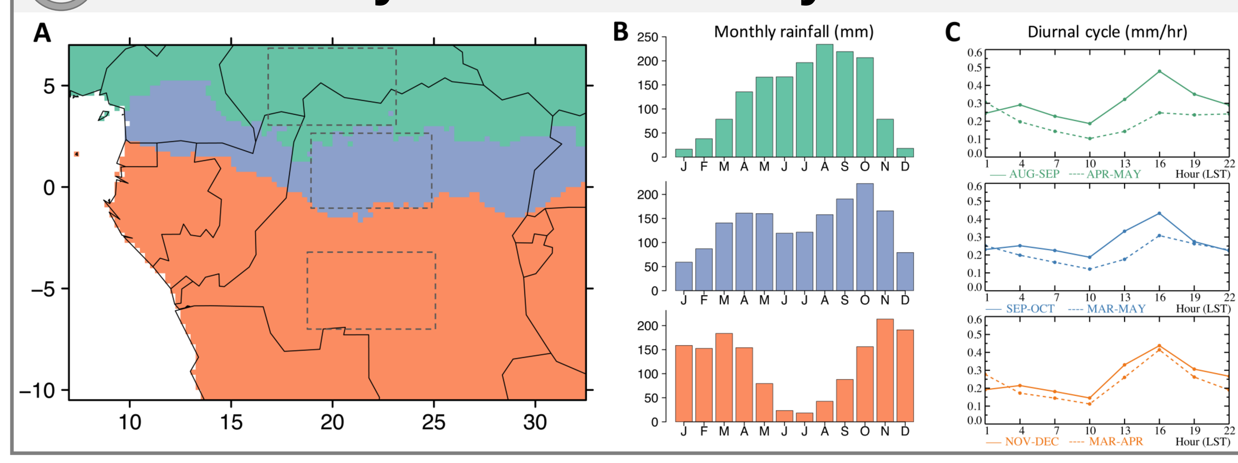


3 Climatic Features Affecting Africa



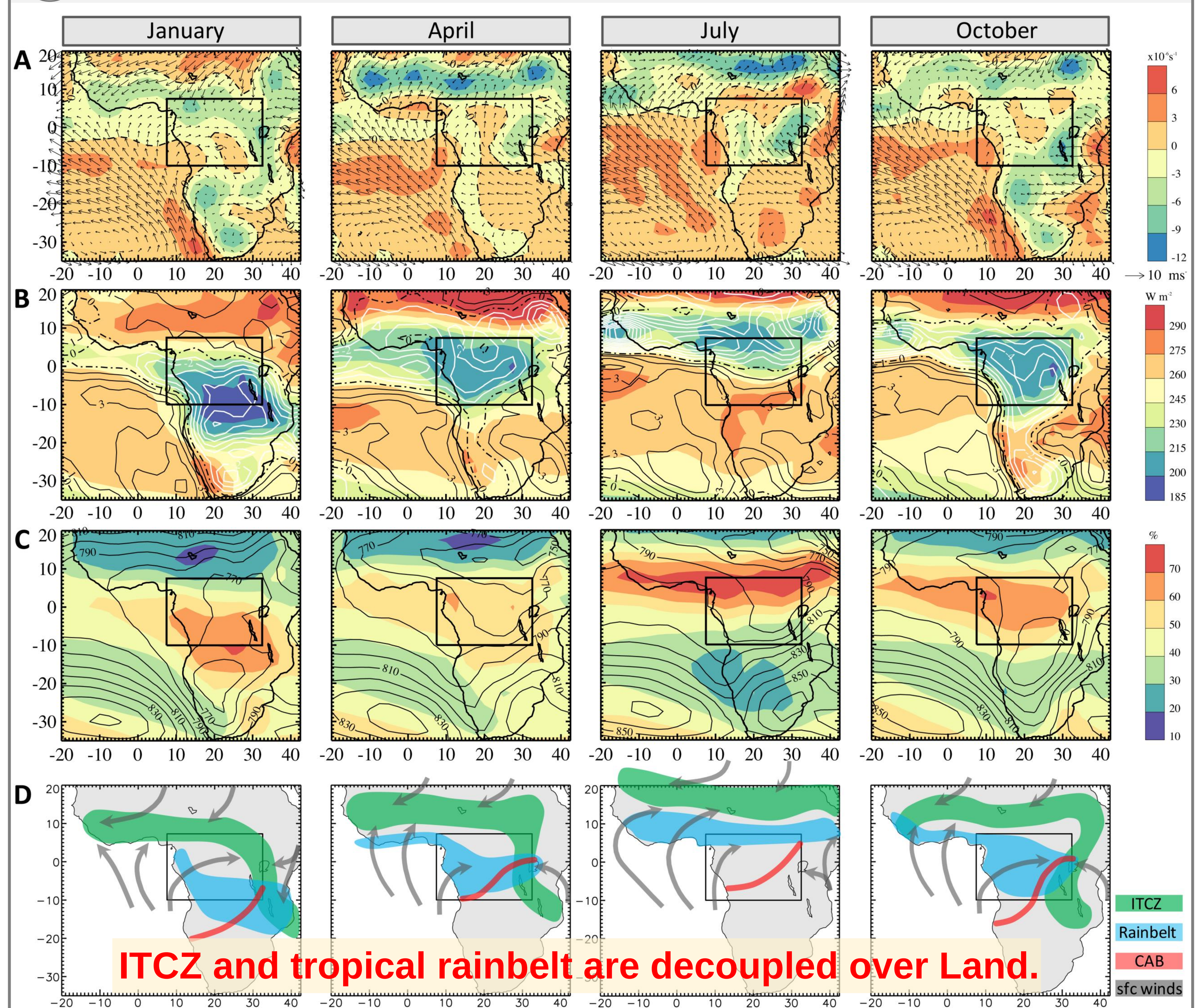
- African Easterly Jet/North (AEJ-N), Tropical Easterly Jet (TEJ), Low-Level Westerly (LLW), African Easterly Wave (AEW), Saharan Heat Low (SHL): *Jun-Sep*
- AEJ-S: *Sep-Nov*
- Zonal Asymmetric Pattern of Precipitation (ZAP): *Dec-Mar*
- Atlantic Meridional Mode: *Mar-May*
- Atlantic Cold Tongue/Atlantic Niño: *Jun-Aug*
- Summer (*Jun-Sep*) & Winter (*Dec-Mar*) Indian Monsoon
- Indian Ocean Dipole (IOD) Mode: *Sep-Oct*

4 Annual Cycle & Diurnal Cycle of Rainfall



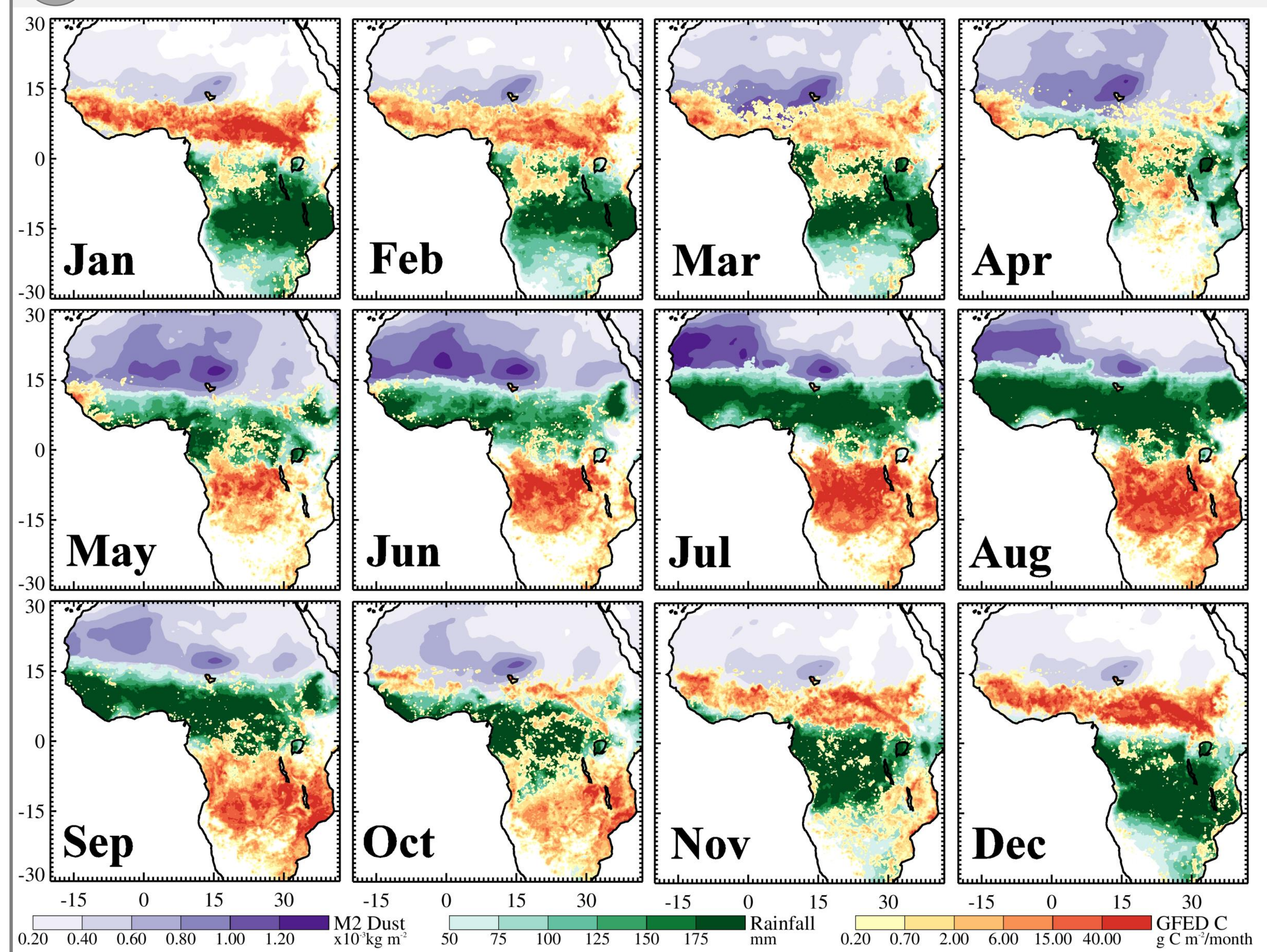
(a) Homogeneous regions with respect to annual cycle of rainfall. (b) corresponding mean annual cycle for each region. (c) diurnal cycle of rainfall for select rainy seasons averaged over areas shown with dashed boxes at the center of each homogeneous region in (a). Unlike rainfall, surface air temperature does not present a strong annual cycle (not shown).

5 Mean Patterns of Different Meteorological Variables



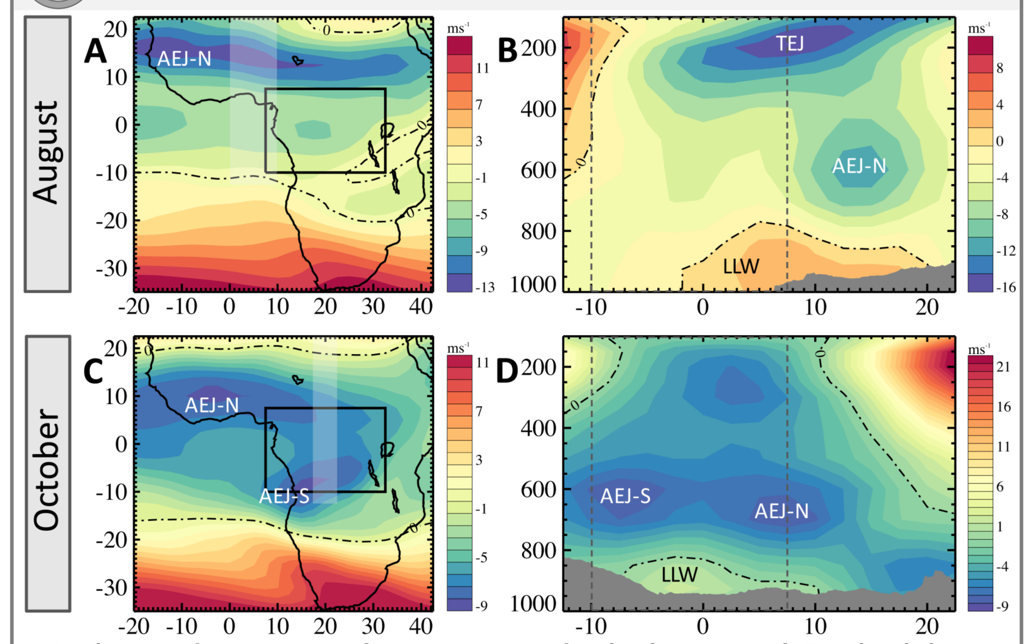
(a) divergence (shadings) and horizontal wind vectors at 925 hPa; (b) OLR (shadings) and vertically averaged (850–200 hPa) omega (contours, described in 10^{-2} Pa/s). Black/white contours represent downward/upward motion, respectively; (c) vertically averaged (1000–300) relative humidity (shadings) and low-level (925 hPa) geopotential heights (contours, described in m); (d) schematic of the Intertropical Convergence Zone (ITCZ), Congo air boundary (CAB), tropical rainbelt, and surface winds, based on panels (a)–(c) and previous studies.

6 Monthly Mean Patterns of Dust, Rainfall & C Emission

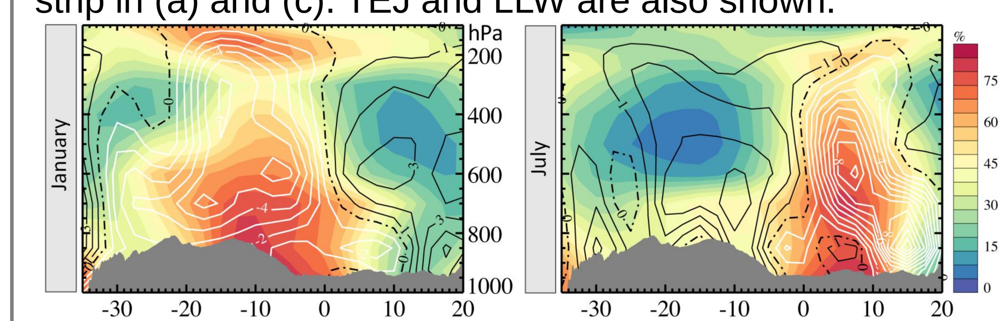


Dust is from MERRA-2, rainfall from TMPA, and C from Global Fire Emissions Database (GFED). The tropical rainbelt and region of maximum biomass burning have both a meridional excursion but in opposite directions. Dust has an annual cycle, but is geographically confined to the Sahara-Sahel.

7 Regional Jets and Circulation Patterns

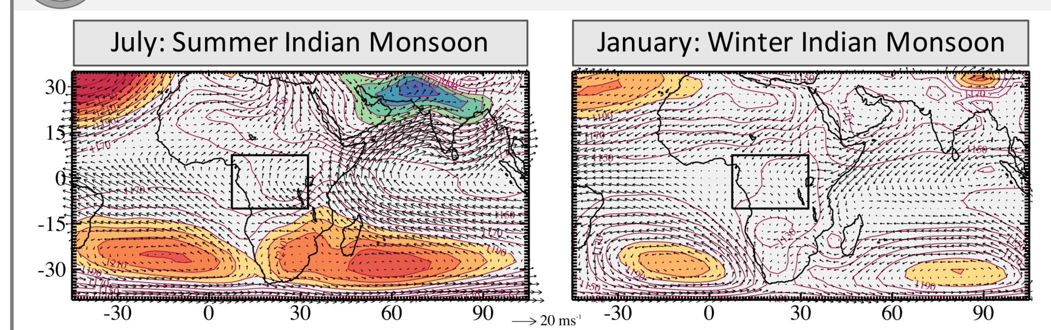


Horizontal pattern of mean zonal wind at 600 hPa in (a) August and (c) October to identify AEJ. (b) Latitude-height cross section of mean zonal wind for these two months, averaged over longitudes highlighted with the transparent strip in (a) and (c). TEJ and LLW are also shown.



Latitude-height cross section (averaged over 17E–22E) of mean relative humidity (shadings) and omega (contours).

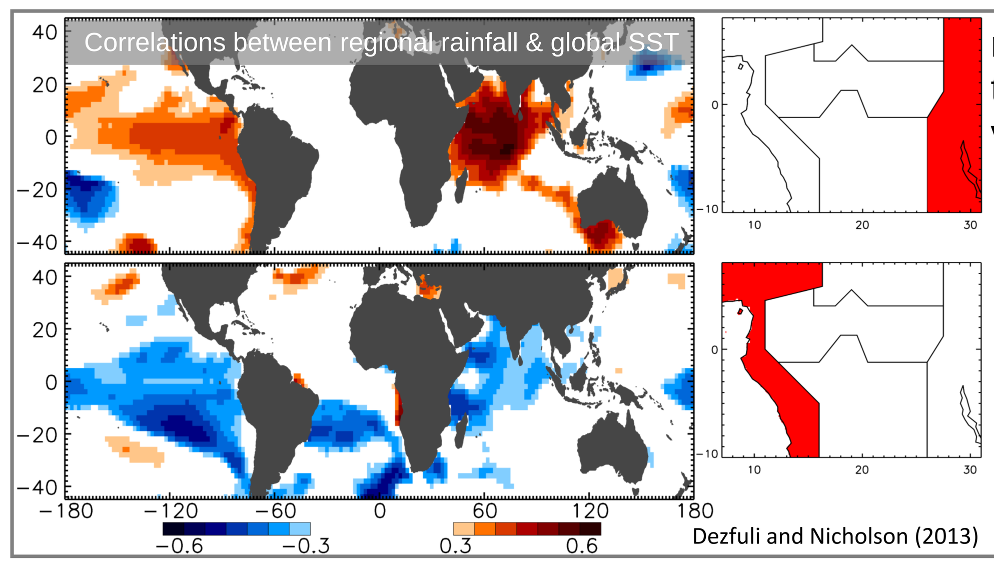
8 Indian Monsoon



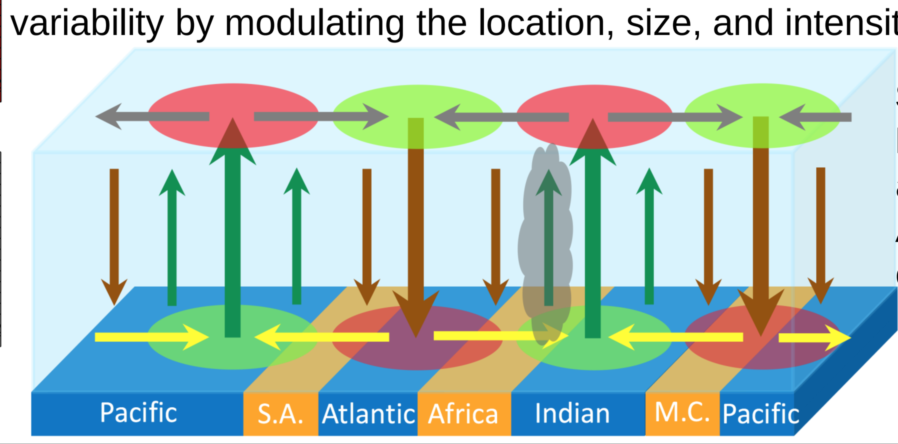
Mean low-level horizontal winds and geopotential heights (contours) to identify the southwesterly and northeasterly winds representing summer and winter Indian monsoon systems, respectively, as well as Mascarene and St. Helena Highs.

9 Remote Forcing on Rainfall

Congo Basin is regionalized based on interannual variability of rainfall. Regional mean rainfall of the eastern and western sectors show strikingly opposite responses to global SSTs and atmospheric circulation. The central regions act as a transition zone with very weak links to those features. Without an objective regionalization this strong signal would be missed! The inverse patterns are attributed to the remote forcings that are manifested as atmospheric bridges and control rainfall variability by modulating the location, size, and intensity of the zonal circulation cells.



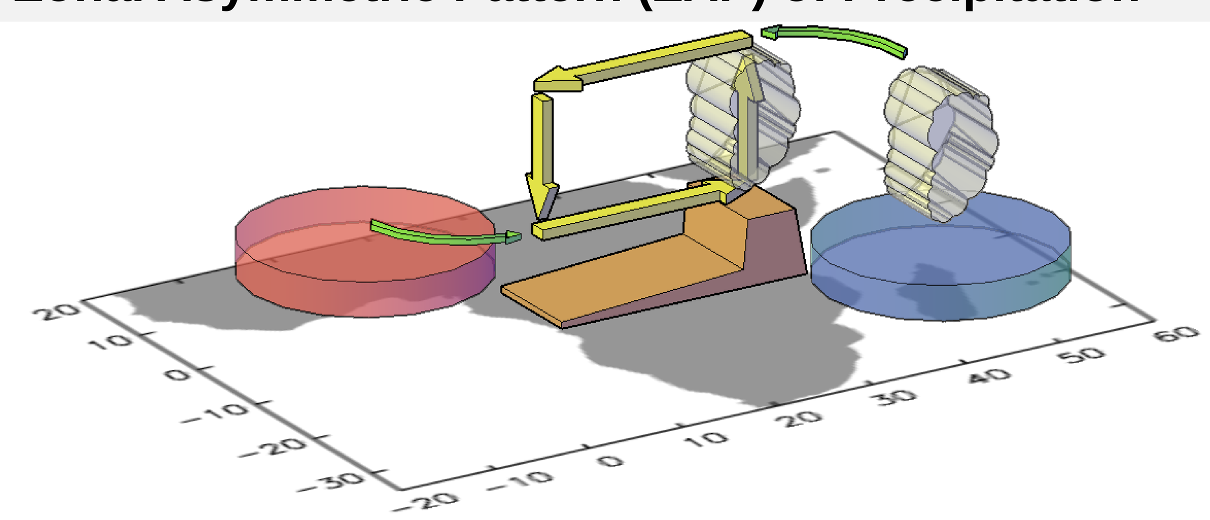
Dezfuli and Nicholson (2013)



Schematic of an Atmospheric Bridge, showing how two adjacent zones within equatorial Africa are inversely related to changes in the remote oceans.

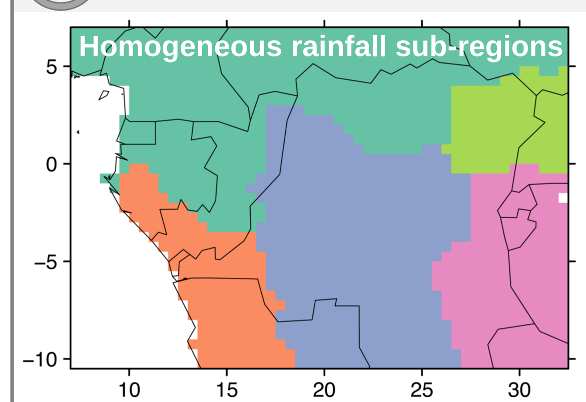
Diverg. Converg. Rain

10 Zonal Asymmetric Pattern (ZAP) of Precipitation

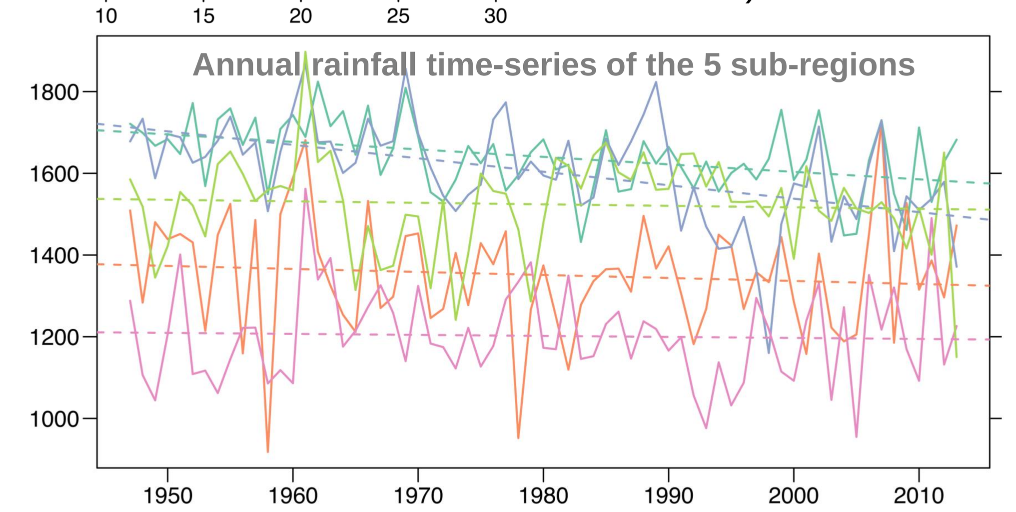


Schematic illustration of ZAP during its positive phase (Dezfuli et al. 2015). This zonally overturning circulation over south equatorial Africa presents the leading mode of synoptic-scale variability in the region during December-March. The red (blue) regions represent positive (negative) pressure anomalies. The resulting interhemispheric pressure gradient controls ZAP. During a negative phase, the convective cell shifts westward. ZAP relies on climatic communication between eastern and western equatorial Africa—two regions that are generally treated as climatically separate units.

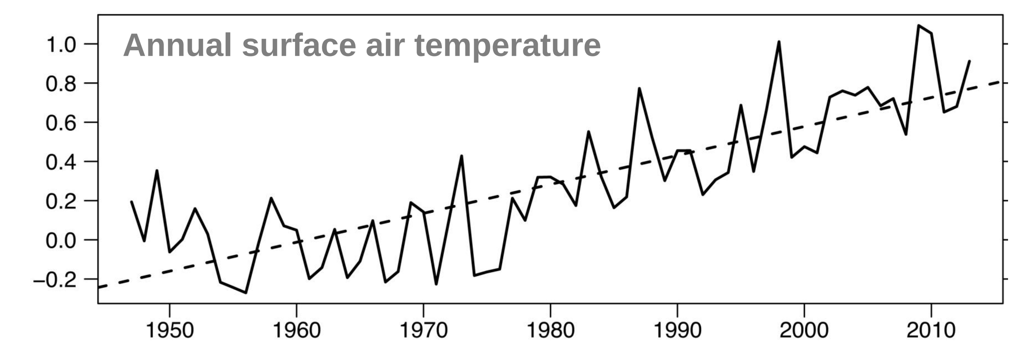
11 Trends in Annual Rainfall & Temperature



The region is objectively divided into five homogeneous sub-regions with respect to similarity of the interannual variability of annual rainfall, using the *HiClimR* package (Badr et al. 2015).



Negative rainfall trend over the southern Congo Basin has been attributed to the decrease of local moisture recycling due to deforestation and the large-scale ocean-atmospheric dynamics.



Unlike rainfall, the annual temperature does not show strong spatial heterogeneity, so the entire region is represented with one time series that shows a strong warming trend.

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