On the Mechanisms Controlling the Rainy Season Transition Period in the Southern Congo Basin

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Research Motivation

Background: Changes to the Congo Basin water cycle include longer dry seasons[1] and April-June drought[2]. How will the Congo Basin respond?
Problem: Fragmented understanding of what controls transition periods to its rainy seasons limits our ability to understand its response.
Goal: Identify those key mechanisms, including the role of evapotranspiration (ET) in providing atmospheric moisture.

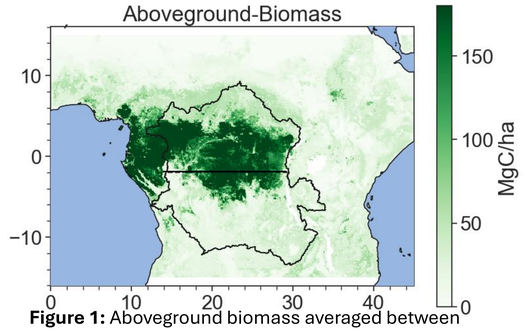


Figure 1: Aboveground biomass averaged between 2000-2020. Horizontal black line at 2° S denotes the divide between the northern and southern Congo Basin. Black outline denotes the basin water shed area.

Methods: Defining Transition Periods

We defined three phases during the transition to the rainy season onsets.

Pre Transition Turning point in divergence

Early Transition Turning point in CWV

Late Transition MFC convergent for the first time

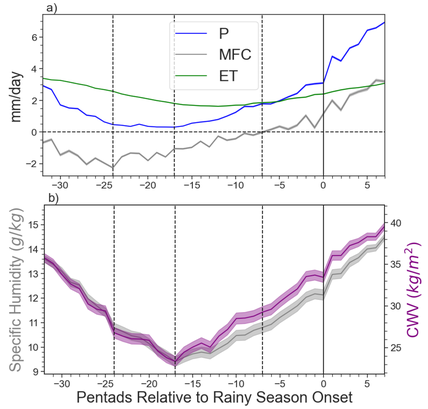


Figure 2: a) Precipitation (P; TRMM), vertically integrated moisture flux convergence (MFC; ERA5), and ET (GLEAM) relative to the rainy season onset (RSO); b) surface specific humidity and column water vapor (CWV; AIRS). Average rainy season onset date was October 10.

Results, Pre-Transition: What Controls Moisture Changes?

Surface temperature increases change large-scale temperature gradients, weakening moisture divergence out of the basin.

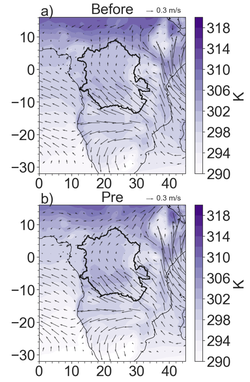


Figure 3: Surface temperature (AIRS) and 850 hPa horizontal winds (ERA5) for a) the "before" period (30 days before the pre-transition); and b) the pre-transition

$$MF = \int_{950}^{600} q\boldsymbol{V}\frac{dP}{g}$$

$$\boldsymbol{V} = (u, v)$$

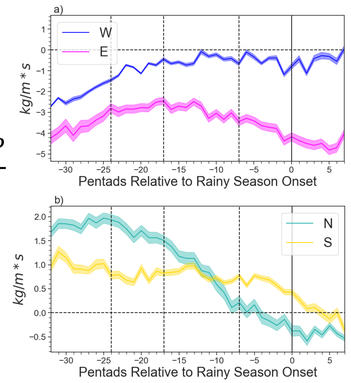


Figure 4: a) W: MF across $14.5°E$. E: MF across $34°E$. Positive means towards the east. B) N: MF across $2°S$. S: MF across $14°S$. Positive means towards the north.

Results, Early-Transition: What Controls Changes in ET?

Insolation outpaces radiation decreases from clouds and biomass burning, increasing photosynthesis and ET.

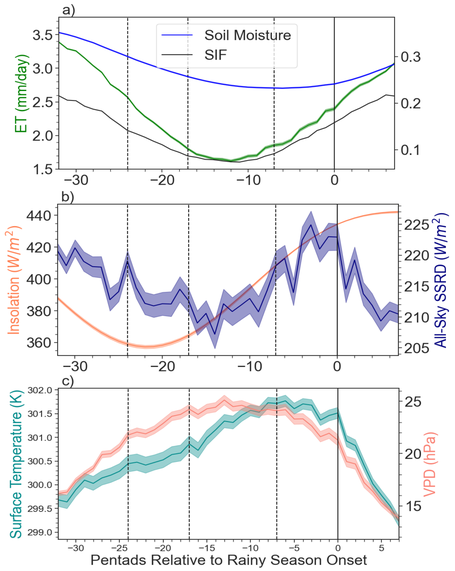


Figure 5: a) ET (GLEAM), rooting-depth soil moisture (SM; mm/day; GLEAM), solar-induced fluorescence (SIF; $mW\ m^{-2}\ nm^{-1}\ sr^{-1}$; OCO-2); b) Insolation and surface radiation (SSRD; CERES); and c) Surface temperature and vapor pressure deficit (VPD; AIRS).

ET and SIF are decoupled from changes in soil moisture, temperature, and VPD.

A random forest model that predicts ET using radiation and water metrics confirms the seasonal control of radiation.

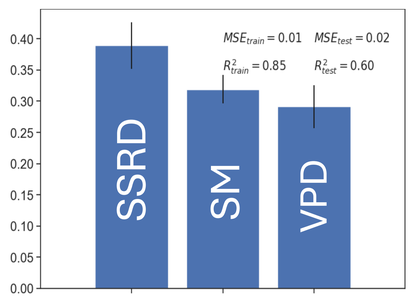


Figure 6: Feature importances of a random forest model predicting ET using surface radiation (SSRD; CERES), soil moisture (SM; GLEAM) and vapor pressure deficit (VPD; ERA5).

Results, Late-Transition: Final Ingredients for Deep Convection?

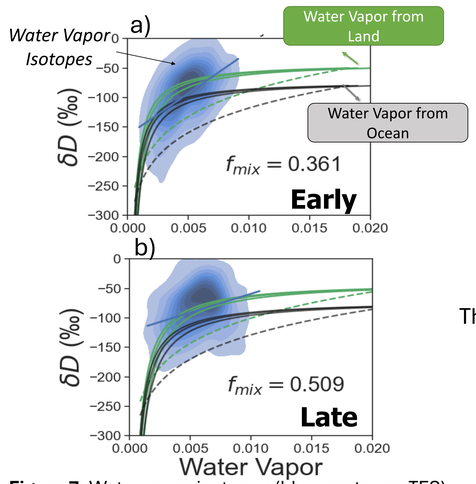


Figure 7: Water vapor isotopes (blue contours; TES) compared to mixing (solid) and Rayleigh (dashed) isotope models that describe changes in water vapor isotopes from land (green) and ocean (grey) for a) the early transition; and b) the late transition.

Early

Ocean moisture contributes the most to atmospheric moisture ($f_{mix} < 0.5$)

Late

Sharp jump in ET contribution to atmospheric moisture ($f_{mix} \approx 0.5$)

ET contributes equally to atmospheric moisture for rainfall.

This moisture uplifts to upper atmosphere for the first time, reflected by increases in atmospheric instability from:

1) Shear from the AEJ-S

2) Mass moisture convergence along the Congo Air Boundary

3) Uplift by the Congo Basin Cell

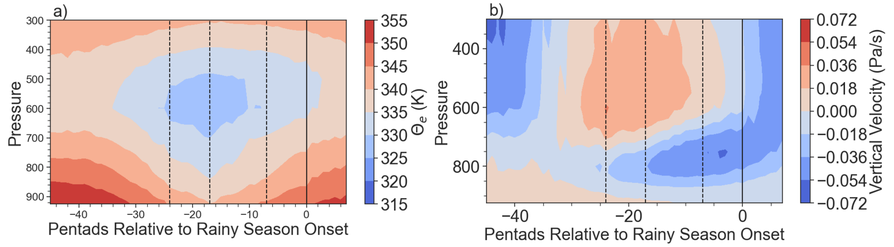


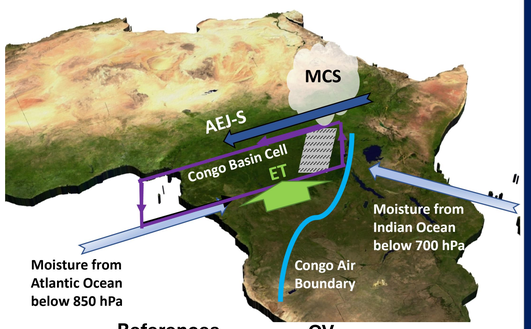
Figure 8: a) Equivalent potential temperature (θ_e; AIRS) ; and b) Vertical velocity (ERA5). Negative means uplift.

Rainy Season Onset Mechanisms

Pre Transition
Seasonal drying continues but moisture advected out of the basin decreases.

Early Transition
ET begins to increase, controlled by radiation increases, while more moisture stays within the basin. This supports increases in shallow convection.

Late Transition
Moisture transport and ET work together to increase thermodynamic instability for the rainy season onset.
Atmospheric conditions becomes conducive for deep convection by promoting convergence, dynamic lifting, and shear[3,4,5,6].



References

CV

Looking for a postdoc!

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