Sarah Romahn [1*]
Andreas Mackensen [1]
Jeroen Groeneveld [2]
Jürgen Pätzold [2]

Holocene Monsoon variability in East Africa: a marine perspective

* Sarah.Romahn@awi.de
1 Alfred Wegener Institute for Polar and Marine Research, Columbusstraße, D-27568 Bremerhaven
2 MARUM- Center for Marine Environmental Sciences, Bremen University, Leobener Straße, Bremen, Germany

INTRO

The processes that control climate variability in the African tropics are poorly understood. We reconstructed sea surface temperatures (SST), foraminiferal Ba/Ca based sea surface salinity (SSS) estimations as well as seawater $\delta^{18}O$ of the western Indian Ocean for the past 12 kyrs on a sediment core (GeoB12615-4) offshore Tanzania, to determine what modulates Holocene precipitation changes in East Africa.

OVERVIEW

The sediment core GeoB12615-4 was retrieved during Meteor cruise M75/2 in 2008 at 07°08.30´S 39°50.45´W (446 m water depth) off Tanzania. It is located close to the **Rufiji River delta**.

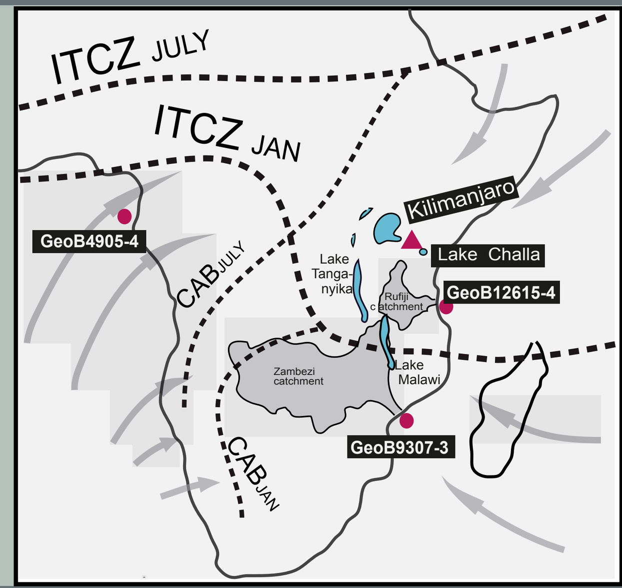

Figure 1): Overview of East Africa. Great Lakes in light blue, catchment areas of Zambezi/ Rufiji River in grey, marine sediment core locations in pink. Mount Kilimanjaro is displayed as pink triangle. The dashed line shows the position of the ITCZ during Northern Hemisphere summer and winter. The thin dashed line indicates the location of the associated Congo Air Boundary (CAB). After Schefuß et al., 2011 and Ivory et al., 2011.

QUESTION

Many factors contribute to the variability of East African Monsoonal precipitation during the holocene, such as

1. Indian Ocean SST or
2. the position of the ITCZ (Intertropical Convergence Zone)

But to what extend and how are they represented in our records?

RESULTS

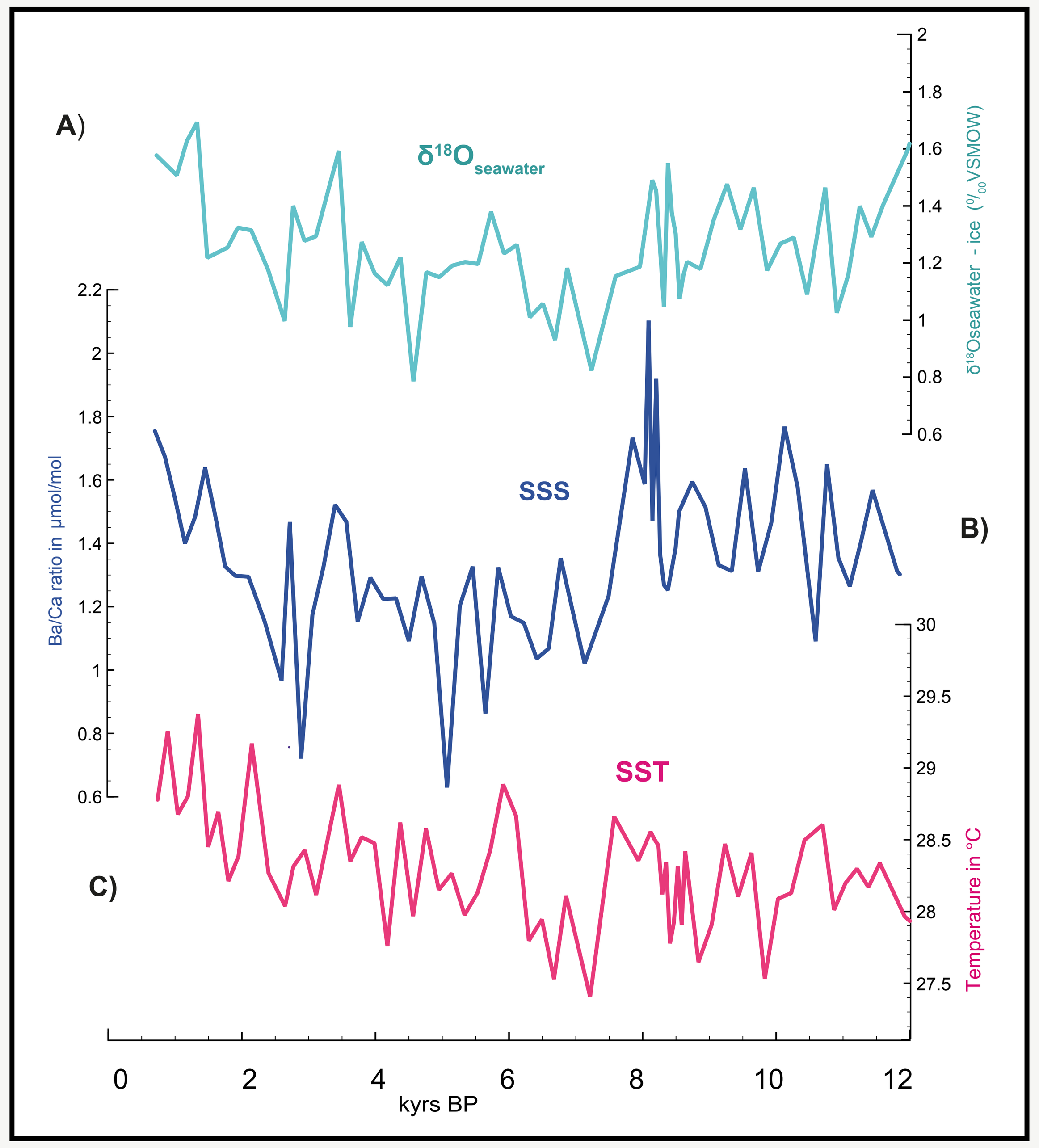

Figure 2): proxy data of GeoB12615-4, measured on *G.ruber* white s.s.(250-300µm) **A**) $\delta^{18}O_{seawater}$, icevolume -corrected (Siddall et al, 2003 and Waelbroeck et al., 2003) in $^0/_{00}$VSMOW) **B**) SSS estimations based on Ba/Ca in µmol/mol. **C**) SSTin °C, based on Mg/Ca.

We present $\delta^{18}O_{seawater}$ (ice volume-corrected, in $^0/_{00}$VSMOW), Ba/Ca-based past sea surface salinity (SSS) estimations and Sea Surface Temperature (SST) reconstructions, based on Mg/Ca ratios, of sediment core GeoB12615-4 (Fig. 2). We used *Globigerinoides ruber* white, s.s. (250-300µm) for all measurements. Ba/Ca and $\delta^{18}O_{seawater}$ are often used to determine past SSS, since in the vicinity of river deltas SSS is strongly influenced by river runoff, hence reflecting precipitation changes in the rivers´ catchment. Note that our records A) and B) do not correlate. The age model is based on nine AMS radiocarbon ages, with ΔR=140yrs (Southon et al., 2002).

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DISCUSSION

Since the Ba/Ca record does not correlate to our reconstruction of $\delta^{18}O_{seawater}$ during the mid- and late Holocene (Fig. 3), we conclude that the oxygen isotopy of the seawater is partly influenced by $\delta^{18}O$ changes of the Rufiji River water, rather than solely reflecting past SSS.

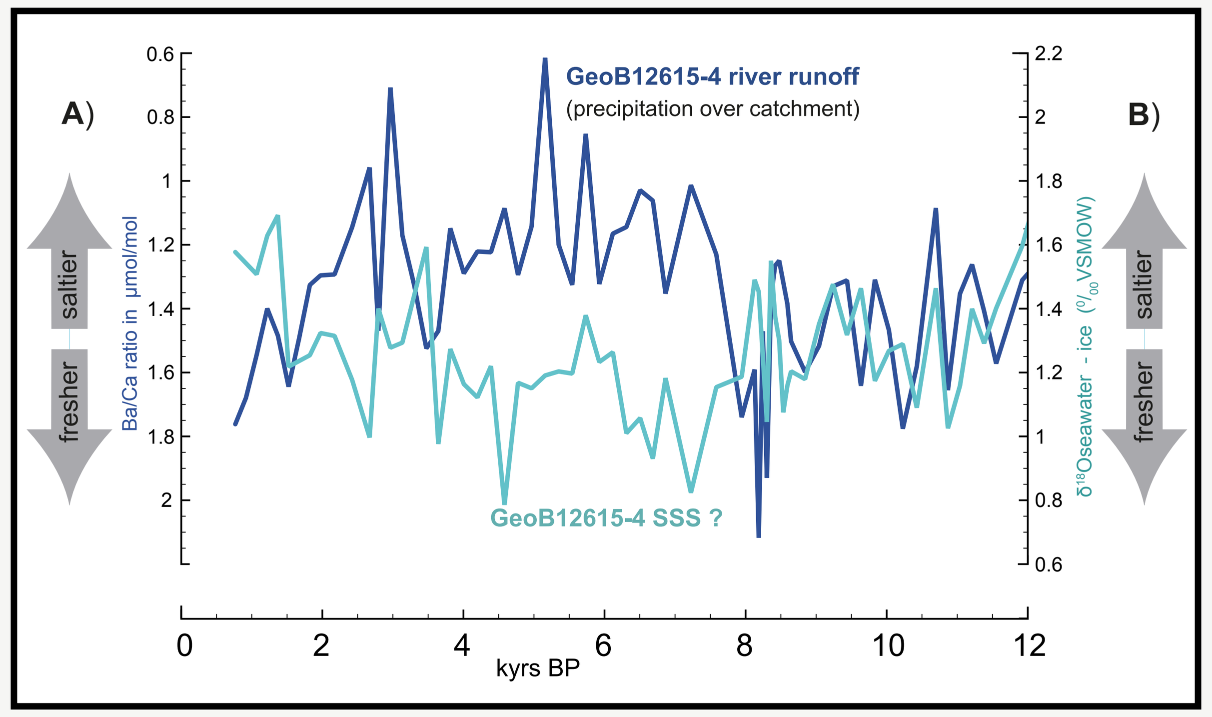

Figure 3): Comparison of both records of GeoB12615-4, which should reflect past Sea Surface Salinity: **A**)Ba/Ca record of GeoB12615-4 in µmol/mol. **B**) $\delta^{18}O_{seawater}$ record of GeoB12615-4 in $^0/_{00}$VSMOW.

We compared the $\delta^{18}O_{seawater}$ record to the $\delta^{18}O$ record of the Kilimanjaro ice core (Thompson et al., 2002), as the latter represents the isotopic variability of East African precipitation for the Holocene (Fig. 4).

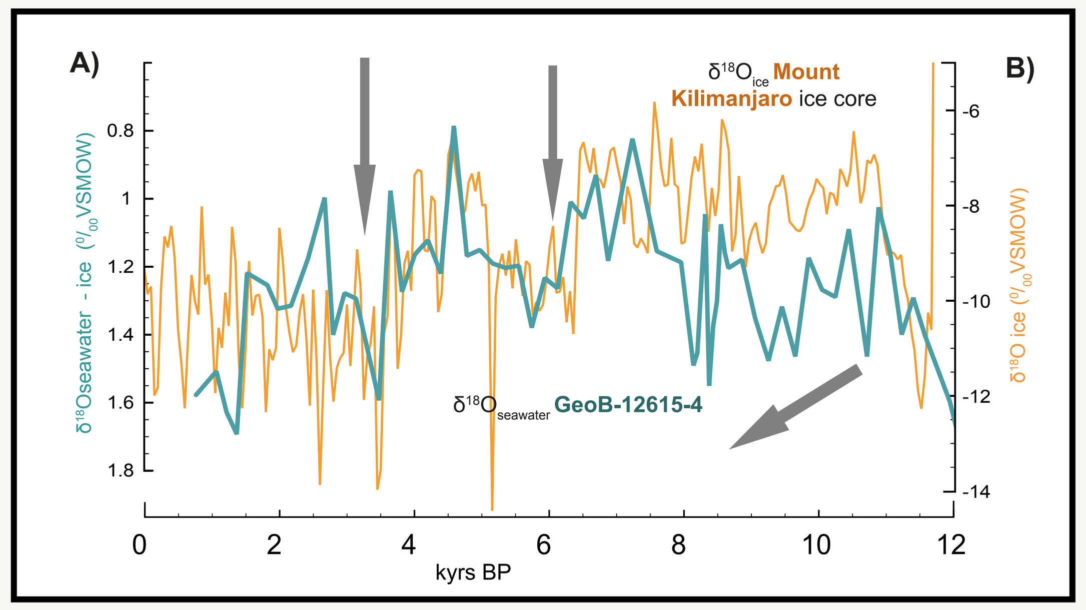

Figure 4): **A**) $\delta^{18}O_{seawater}$ of GeoB12615-4 and **B**) the Mount Kilmanjaro ice core record (KNIF core) in 50-year average in $^0/_{00}$VSMOW (orange). Note that A) y-axis is reversed.

The rough correlation (Fig. 4) suggests that our $\delta^{18}O_{seawater}$ partially reflects changes in res-ponse to varying $\delta^{18}O$ in West African precipitation.

1 SST gradients and CAB

As proposed recently, longitudinal shifts of the Congo Air boundary (CAB) play a role in modulating precipitation (Tierney et al., 2011 and Junginger, 2011). These shifts also change the trajectory of Indian Ocean moisture into the continent and therefore affect $\delta^{18}O$ of the East African rainout.

The position of the CAB (Fig. 1), dividing the rainwater range of Indian Ocean and Atlantic Ocean, depends on SST gradients within and between oceans. We calculated a difference (ΔSST) of our record and GeoB4905-4 from the tropical Atlantic (Weldeab et al., 2005, Fig. 1), showing that ΔSST variability resembles the pattern of the Kilimanjaro ice core record (Fig. 5).

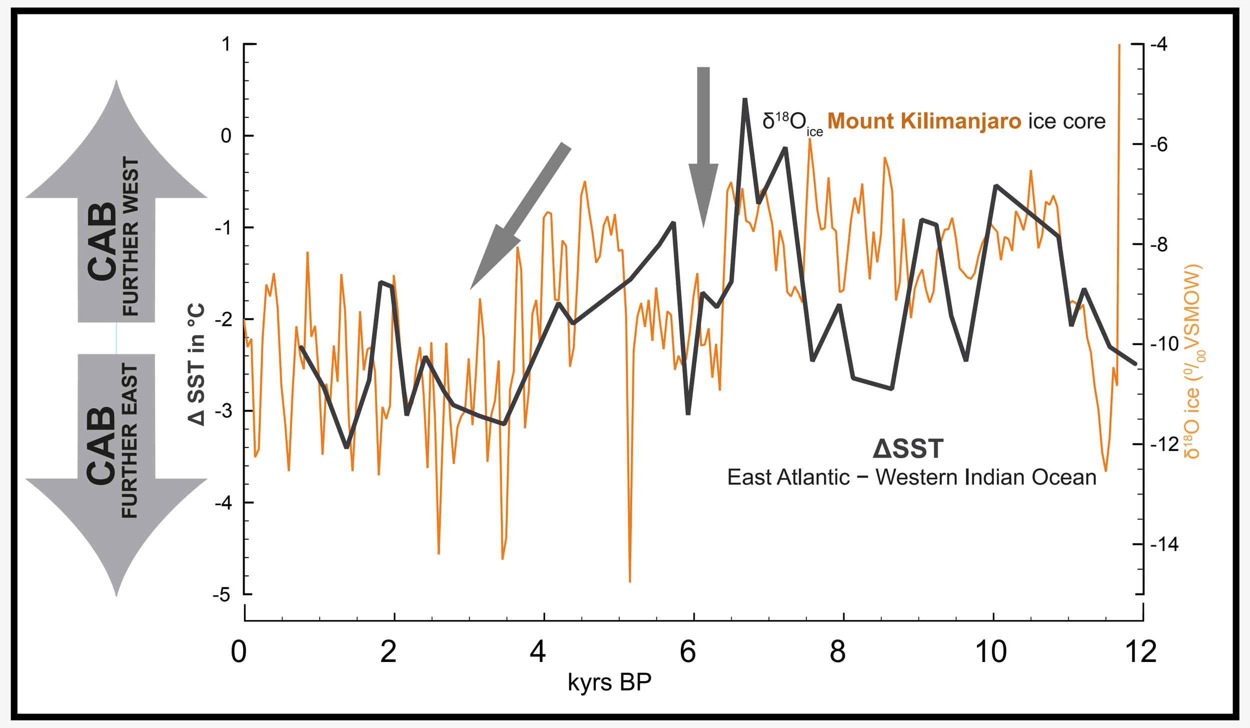

Figure 5): Comparison of the Mount Kilimanjaro ice core record (orange) and constructed ΔSST: difference of Sea Surface Temperatures between GeoB4905-4 (off Cameroon) and GeoB12615-4 (off Tanzania) in Δ°C. Arrows indicate position of CAB during N- Hemisphere summer over African continent.

We argue that both oxygen isotope records (GeoB12615-4 and Kilimanjaro ice core) partially reflect changes in the rainwater isotopy (rather than SSS or temperature variability), which is controlled by SST gradients between the tropical oceans surrounding Africa.

2 Position of the ITCZ

A more southerly position of the Intertropical Convergence Zone has been suggested to explain the prevalent aridity in North and East Africa during glacial periods and, in particular, during short-term cold events, such as the Younger Dryas (Castaneda et al., 2007, Johnson et al., 2002).

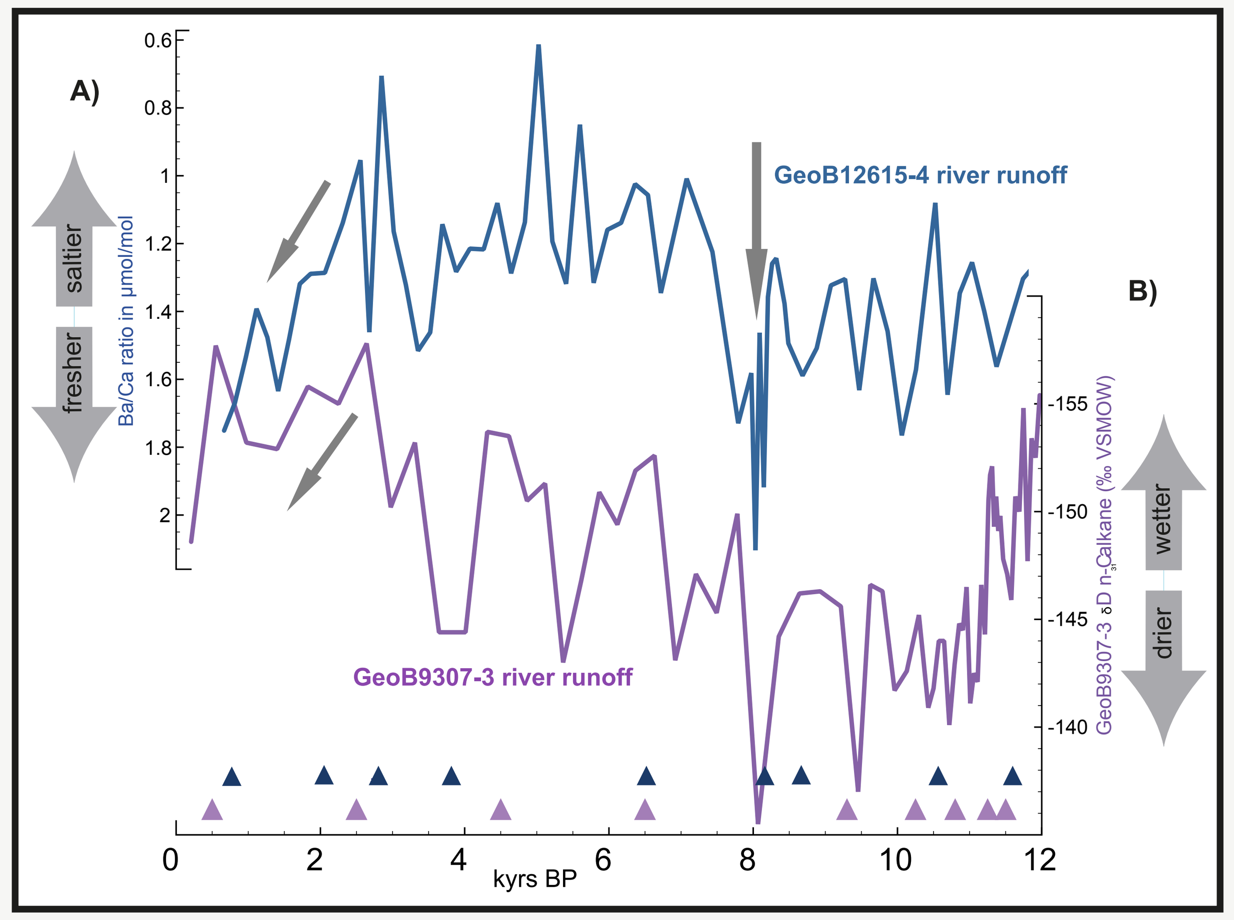

Figure 6): Comparison of **A**) Ba/Ca-ratios in µmol/mol of core **GeoB12615-4** and **B**) δD n-C[31] alkane (‰ VSMOW) of core **GeoB-9307-3.** Purple triangles indicate radiocarbon ages of GeoB9307-3, blue triangles those of GeoB12615-4. Grey arrows indicate shifts to wetter/fresher or drier/saltier conditions. Note that the Ba/Ca y-axis is displayed inverse.

Our Ba/Ca record, as a proxy for the amount of river water reaching the ocean, anticorrelates with a record of precipitation changes over the Zambezi River catchment, derived from plant waxes (Schefuß et al., 2011, Fig.6). So, during dry phases in Southeast Africa (Zambezi record) East Africa (our record) receives more rainfall and vice versa.

We argue the anticorrelation reflects a "swinging" SH summer position of the ITCZ during the Holocene.

CONCLUSIONS

Whereas the ITCZ is considered to be the dominant control on Holocene hydroclimate, the CAB has a relevant impact on the regional distribution of precipitation as well. This has to be taken into account when comparing near-shore proxy data to terrestrial records.