EGU21-5923, updated on 17 Jan 2022
https://doi.org/10.5194/egusphere-egu21-5923
EGU General Assembly 2021

How dry was the LGM? A Biosphere-Hydrosphere modelling approach for the paleo-lake Chew Bahir and Omo-River catchment in southern Ethiopia

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The formation of the East African Rift System led to the emergence of large topographical contrasts in southern Ethiopia. This extreme topography is in turn responsible for an extreme gradient in the distribution of precipitation between the dry lowlands (~500 mm a^{-1}) in the surrounding of Lake Turkana and the moist western Ethiopian Highlands (~2,000 mm a^{-1}). As a consequence, the prevailing vegetation is fractionated into a complex mosaic that includes desert scrubland along the Lake Turkana shore, woodlands and wooded grasslands in the Omo-River lowlands and the paleo-lake Chew Bahir catchment, afro-montane forests of the Ethiopian Highlands, and afro-alpine heath in most elevated parts. During the past 25 ka, southern Ethiopia has been exposed to significant climate changes, from a dry and cold Last Glacial Maximum (LGM, 25-18 ka BP) to the African Humid Period (AHP, 15-5 ka BP), and back to present-day dry conditions. These shifts in temperature and precipitation may have affected the vegetation pattern and landscape in the area, but environmental data especially from LGM times are rare. This is because in times of a dry climate the paleo-lake Chew Bahir was dried up and hence the climate record in lake sediments was interrupted.

In this study, we investigate the hydrological conditions during the LGM using a previously-developed lake balance model (LBM) for southern Ethiopia, which is now coupled with a new predictive vegetation model (PVM) to better understand the biosphere-hydrosphere interactions and thus possible precipitation thresholds. The PVM is based on the method of boosted regression trees using elevation and monthly precipitation as input to predict land-cover, tree-cover and vegetation greenness for a ~1 km grid covering the Omo-River, paleo-lake Chew Bahir, Lake Chamo and Lake Abaya catchments. We linked the PVM and the resulting land surface parameters with the LBM to model the impact of a changing land-cover to the actual evaporation. Furthermore, we used the glycerol dialkyl glycerol tetraethers (GDGT) based paleo-temperature and tropical lapse rate reconstructions from Mount Kenya to consider the orographic temperature distribution in southern Ethiopia during the LGM. Using both, we simulated different precipitation amounts from 100% to 50% compared to the modern-day multi-annual averages and their effect on vegetation and lake levels of paleo-lake Chew Bahir. Our biosphere-hydrosphere modelling

approach suggests 25 to 30% lower moisture availability during the LGM compared to the modern conditions and provides a high-resolution spatial reconstruction of the potential prevailing vegetation in the southern Ethiopian region.