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Interactive comment on "Expressions of climate perturbations in western Ugandan crater lake sediment records during the last 1000 yr" *by* K. Mills et al.

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GENERAL COMMENTS

This paper aims to contribute to the documentation of decadal to century-scale hydroclimatic variability in the western portion of equatorial East Africa over the past millennium, in order to promote evaluation of the synchronicity and spatial extent of past climatic changes. This in turn may improve insight into the climate-dynamical processes causing this variability in rainfall and drought over time. The authors reconstruct past hydroclimate variation using the changes in lacustrine diatom communities resulting from lake-level fluctuations and salinity changes in two neighbouring crater lakes situated to the east of Lake Edward in the Rift valley of western Uganda. Fossil assemblages of these diatom communities are preserved in the lakes' bottom sediments, allowing climate-driven changes in the relative abundance of individual diatom species to be traced through time. Changes in lake level are inferred from the relative proportion of planktonic (open-water) and periphytic (substrate-bound) diatom species; changes in salinity (concentration of dissolved salts, measured by its electrical conductivity) are inferred using the authors' previously published (Mills & Ryves, 2012) weighted-averaging transfer function relating the modern-day distribution of diatom species in western Ugandan lakes to the gradient in salinity covered by those lakes. The study of paired sediment records from neighbouring lakes is intended to help discriminate site-specific hydrological and ecosystem responses from signatures of the supposedly identical climate history experienced by both lakes.

The methods of diatom paleoecology employed in this study are state-of-the-art, and include numerical zonation of the stratigraphic distribution of diatom species; detrended correspondence analysis (DCA) to explore the main patterns of change in the recovered fossil diatom assemblages (however the results of this analysis are not presented); and redundancy analysis (RDA) to investigate the relationship between temporal changes in assemblage composition and in selected possible drivers of these changes. Unfortunately, good methods of diatom paleoecology by themselves do not produce a robust climate reconstruction, nor a robust reconstruction of ecosystem response to climate change. Climatic inferences based on signatures of biological change preserved in lake sediments are often hampered by incomplete understanding of the ecological requirements and habitat preferences of individual diatom species (here, the local variant of Cyclotella meneghiniana is a good example); of the relationship between habitat change and hydrological (lake level, salinity) change; and of how climate trends at the time scale of interest interact with the site-specific hydrology of each study lake. Authors often try to circumvent some of this complexity by shifting a study's focus to reconstructing ecosystem response to climate rather than climate history itself, even though evidence of the major restructuring of a lacustrine ecosystem (nutrient cycling, communities, food web, etc.) through time says more about its hydrological sensitivity to climate change than about the actual magnitude of climate change; after all, temporary ponds dry out every year. Exactly in those lakes that are sensitive enough to respond strongly to the relatively modest hydroclimate variability of the past millennium, producing a trustworthy reconstruction from the sedimentary signatures of this response is challenged further by cryptic stratigraphic hiatuses and sedimentation-rate variability that cannot be constrained by 14C dating, old-carbon age offsets larger than the duration of events being reconstructed, reworking of plant macrofossils during lowstands, etc. This study has more than its fair share of such problems, compromising any definitive statement about what actually happened, and certainly about exactly when climate-driven or anthropogenic ecosystem changes are supposed to have happened. The paper is also marred by a piecemeal description of recorded diatom patterns, by inconsistencies between text and figures, and by several erroneous statements (see below).

Despite these obvious defects, Mills et al. present valuable paleoecological data, and contingent on a (really) major revision of this paper a reasonably robust story of environmental change in western Uganda can be distilled from them. In my opinion, this revision should include the following:

1) Even when accepting the authors' selection of retained and excluded 14C dates, the presented age-depth relationship for both sediment records depends upon the smoothing parameter (0.5) chosen for the spline curve which interpolates between dated horizons; adding a reasonable spread of feasible smoothing parameters to the analytical and age-model uncertainties reflected in the width of the grey error envelopes of Figs.2-3, it is easy to see that the timing of diatom zone boundaries can be estimated only to the nearest century at best. This uncertainty should be reflected in the age assignment of those zones in the Results section.

2) Given this large chronological uncertainty, it is futile to portray the diatom-based reconstructions of lake history as independent reconstructions of regional climate his-

tory. Rather, I recommend to use the Lake Edward %Mg record (Russell & Johnson, 2007), being a better dated and less ambiguous record of past hydroclimatic change in western Uganda (cf. Tierney et al., 2013), as the climatic reference frame for this study, and to focus the paper on answering one question, namely to what extent long-term ecological changes in Nyamogusingiri and Kyasanduka can be explained by lake response to climate change, to anthropogenic disturbance, or to some other proximate driver. The available data simply do not allow to simultaneously "assess ecosystem response to long-term climate and environmental change [and] testing responses to multiple drivers" (Abstract, lines 10-12). Note also that in the present manuscript, exactly the Lake Edward %Mg record is strikingly missing from redundancy analysis of the 'potential regional drivers' of diatom community changes at the study sites (Table S1). This perhaps explains why the general patterns of change in the two study lakes are, somewhat surprisingly, "comparable to trends observed elsewhere in East Africa (e.g., Lake Naivasha)" (p.5198, lines 4-5).

3) Redundancy analysis can play a role in this exercise, but looking for correlation between the diatoms and possible drivers in short sections of time is misguided, due to century-scale uncertainty in the temporal link between the time series of predictor and response variables. Hence, the conclusion on p.5197 that "redundancy analysis suggests that diïňĂerent processes have inïňĆuenced lake ecosystem response and that change in the aquatic ecosystem has had diïňĂerent triggers through time" has no basis in fact.

4) The main text must be entirely revised with clear separation between (and correct attribution of) inferences of climate change, inferences of lake hydrological response to climate change, and inferences of diatom response to lake hydrological change.

5) Diatom stratigraphy can be most conveniently described using text references to the succession of numbered zones shown in Fig. 4. This is now largely lacking, giving the impression that Mills et al. do not attach much value to their numerical zonation. Consistency should also be improved in the description of an increase or decrease of

particular diatom species (a trend), a minimum or maximum of the same (a situation), and their appearance or disappearance (an event); when describing temporal patterns these are not trivial distinctions.

6) The apparently contrasting lake-level history of the two study lakes (their "individualistic response") refers to the opposed temporal patterns in the curves of % planktonic diatoms shown in Fig. 5j and 5k. Since also the diatom stratigraphies of Fig. 4a and 4b are plotted on a linear time scale, the shapes of these curves should be identical in both pairs of figures. For Kyasunduka this seems to be the case, but for Nyamogusingiri the % planktonic curves in Figs. 4a and 5k are clearly different. Due to a possible plotting error in Fig. 5k, it has a crippling impact on the study's conclusions as presently stated. When comparing the % planktonic curves in Fig.4 directly against each other, their temporal patterns through time are in fact quite similar, with two multi-decadal peaks between ca. 1150 and 1370 AD, a prolonged maximum in the period ca.1400-1750 AD, and mostly low values since then. Evidently, a broadly similar moisture-balance history of these two neighbouring lakes over the past millennium is more easily defendable than contrasting histories. The main problem then becomes that both study lakes appear to have experienced high lake level during much of the Little Ice Age period, when the Lake Edward %Mg record indicates prolonged regional drought. But do high values of % planktonic diatoms really reflect high lake level, and vice versa? In these shallow lakes, episodes of low lake level may exclude periphytic diatoms because wave-induced resuspension of soft bottom muds increases turbidity, eradicating the lake-fringing beds of submerged macrophytes that would constitute a suitable substrate. Conversely, high lake level improves water-column transparency for submerged macrophytes, and may promote the water-column stratification which turns the bottom sediments into a nutrient sink, limiting pelagic diatom production. An inverse relationship between % planktonic diatoms and lake level admittedly causes the problem that maxima in diatom-inferred conductivity then correspond to inferred highstands, when the lakes' residence time is lowest. But what is the uncertainty envelope of the presented conductivity reconstructions? And how well constrained are the

distribution patterns of the local diatom species with high conductivity ‘optima’? These are the sort of deliberations that need to be made before diatom-assemblage data can be treated as proxy climate data.

SPECIFIC COMMENTS

Abstract

Line 6: ‘smaller-scale’ studies are less extensive, exploratory studies? Line 19: insert “these two” before “Ugandan”. Lines 22-25: considering the problematic interpretation of these two records, this last paragraph sounds rather hollow.

Introduction

p.5185 lines 25-28: Nicholson et al. (2013) deal with the notably under-documented history of temperature variability in tropical Africa during the past 2000 years; the “complex, regional patchwork of climate regimes” you refer to concerns the better-documented history of moisture-balance variability. p.5186 lines 18-19: Incorrect; in a sub-humid climate regime, a small catchment-to-lake area ratio reduces a lake’s sensitivity to precipitation, because of the smaller contribution of stream or other overland inflow to the lake’s water budget.

3.1 Coring, physical analyses and radiometric dating

Line 24: “across” the two cores? 3.2 Diatom analysis Line 10: these numbers are higher than the length of the core sequences in cm, questioning the earlier statement that diatoms were counted at 1-cm intervals.

3.3 Numerical methods

Line 6: DCA was used to “explore patterns of taxonomic variation among sites”? Line 15: sunspots don’t drive aquatic environments, they are only a proxy of solar radiation; and the sunspot record doesn’t extend to 1000 years ago.

4.1 Core correlation and chronological analyses

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Interactive Comment

Paragraph 3 partly repeats paragraph 2.

4.2 Diatom record

See general comment 5. p.5193, line 12: which littoral/periphytic taxa are referred to here? p.5193, lines 15-18: soil erosion following the stripping of natural vegetation typically results in greater influx of mineral sediments, reducing the organic content of recent lacustrine deposition even if aquatic productivity is enhanced by excess nutrient input. p.5195, line 4: =Fragilaria?

5.1. Lake-level reconstructions

p.5195, lines 10-11: "Reconstructions were based upon the known habitat preferences of the most dominant taxa": as far as I can see, the lake-level reconstructions are simply the summed % of planktonic diatoms. p.5195, line 19: what's your reference for extreme aridity during the 1940s? p.5196, lines 5-8: removal of salts only occurs when water seeps out of the lakes via groundwater. p.5196, lines 17-18: "drier climate coupled with human impacts [post 1800 AD]": the %Mg record from Lake Edward indicates a wetter climate instead. p.5196, line 20: erroneous citation of Bessems et al. (2008).

5.2. Drivers of diatom change

p.5198, lines 15-18: partly repetitive from p.5197, lines 13-15.

5.3. Coherence between records

p.5199, line 15: "There is general agreement"? Gasse (2002) predates much relevant work, and does not even focus on central Africa. p.5200, lines 24-26: insert the appropriate references for this statement: Russell & Johnson (2007), Russell et al. (2007), Tierney et al. (2013). p.5203, line 5: Verschuren et al. (2000).

6. Conclusions

p.5205, lines 14-16: it seems this paired lake study creates more issues rather than less. Do you recommend at least three sites?

Interactive comment on Clim. Past Discuss., 9, 5183, 2013.