

Interactive comment on “Precipitation variability in the winter rainfall zone of South Africa during the last 1400 yr linked to the austral westerlies” by J. C. Stager et al.

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Authors' response to comments by Reviewer #1:

We appreciate this reviewer's helpful comments and suggestions.

1. We agree that mention of relatively dry conditions during the MCA is warranted and we have added that information to the manuscript.
2. We thank the reviewer for catching the mislabeling of the %CO₃ curves in Figure 7, and for noting that two of the taxa in Figure 6 could be listed as "tychoplanktonic," and we have made the suggested changes.

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3. The dotted line for the bulk sediment date in Fig. 3 is not shown because it lies far off the time scale; this is now noted in the corrected caption.

4. The dates are already presented in stratigraphic order in Table 1, although they may not appear to be so because they are also grouped according to the materials dated (macrofossils vs. bulk sediments). We prefer to keep the table in this format.

5. We do not feel that illustrations of the cores are necessary because the text already offers clear information about the composition of the sediments, both verbally and in the %LOI curves.

6. Regarding the reviewer's request for other references from the region: we have added two more such citations to the manuscript. However, data of this resolution are unique in the regional literature, and as a result substantiation through comparison with other records is problematic. The onset of Little Ice Age (LIA) humidity in the record presented here does correspond with what has been inferred to be a sharp drop in sea-surface temperatures ca. AD 1300 at Elands Bay (Cohen et al., 1992), and pollen records from Verlorenvlei spanning perhaps the last ~300 years indicate a marked shift from aquatic to riparian elements in the early to mid-1800s (Meadows et al., 1996), perhaps coeval with the decline in dilute-water taxa in our data following the LIA. Unfortunately, other key records from the WRZ, such as the Klaarfontein pollen record (Meadows and Baxter, 2001), the Cederberg Mountains (Meadows et al., 2010; Scott and Woodborne, 2007a, b), Cecilia Cave (Baxter, 1989), and Princess Vlei (Neumann et al., 2011) are not sufficiently well-dated, or of suitably high resolution for reliable comparison in this paper.

7. We have added the following citations to the list of references for taxonomy and autecology: Taylo, et al. (2007), and the EDDI database (<http://craticula.ncl.ac.uk>). However, the "old papers and books" that the reviewer seems to express dissatisfaction with are also widely respected and commonly used sources of information whose ages have no bearing on their value here. The autecology of the dominant taxa in our

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assemblages, such as *Aulacoseira granulata* and *Cyclotella meneghiniana*, has been well documented for many decades and of course has not changed over the years, hence their value as paleolimnological indicators. If the reviewer prefers to use younger sources of such information, however, we recommend visiting the EDDI website which provides taxonomic information and also shows, for example, that *C. meneghiniana*'s upper conductivity tolerance exceeds that of *A. granulata* by an order of magnitude (we now mention this in the revised manuscript, as well).

7. Apart from making mention of the relative tolerances for conductivity in the two taxa above, we disagree that exhaustive use of quantitative data and lists of specific salinity optima are necessary for this study for the reasons that are stated in the paper, because they can encourage false confidence in the magnitudes of inferred local changes, and because our inferences are strictly qualitative in nature. Our approach to inferring the environmental history of Verlorenvlei, which is fully sufficient for the climatic interpretations presented, is now more fully described in the text but also discussed here as follows:

a. Our primary indicators of dilute, planktonic conditions are *Aulacoseira granulata* and *A. ambigua* which are globally distributed in relatively productive lakes. The main reason why they are often called "tychoplanktonic" is because they often spend part of the year lying on the bottom of a lake when mixing regimes weaken. This is not the same as being truly benthic taxa, however. In East African lakes such as Malawi, Victoria, Tanganyika, and Turkana as well as in several crater lakes in Cameroon, the deep channel of the western arm of Lake Sibaya, South Africa, and in many lakes of Europe and North America, these *Aulacoseira* taxa are essentially planktonic in open waters. When not suspended in the water column, they are in a sense "waiting" to be returned to the euphotic zone by seasonal mixing. They are excellent indicators of relatively deep conditions in comparison to the typically more diverse assemblages of Pennales that are found attached to or crawling upon sunlit benthic microhabitats in relatively shallow waters.

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In contrast, the "tychoplanktonic" *Staurosirella pinnata* and *Pseudostaurosirella* are most commonly found living in benthic habitats in lakes at many latitudes around the world, although such habitats may be disturbed by wave action or offshore transport such that these diatoms may also occasionally appear in the plankton. Many other more strictly littoral taxa occasionally turn up in plankton tows as well, but this is not the same as being primarily adapted to a planktonic lifestyle.

The presence of high percentages of *A. granulata* and *A. ambigua* in Verlorenvlei sediments are best attributed to relatively deep, dilute, and productive habitats under conditions of relatively high P-E. Because significant shallowing and restriction or loss of outflow occurs during every dry season as it must also have done during longer arid periods in the past, taxa that favor high salinities and/or shallow habitats are not as clearly informative in the seasonally blended diatom assemblages of these cores as the taxa that represent wetter, more dilute conditions. The former could presumably represent any time of year in this lake, but the latter represent relatively deep, dilute conditions attributable to the rainy seasons. In other words, the best explanation for having large percentages of these *Aulacoseira* in the cores, as opposed to something like *C. meneghiniana* or more clearly benthic taxa, is an increase in winter rainfall. Those indicator taxa are therefore the focus of our paper. b. As the reviewer correctly notes, increases in the percentages of planktonic *Aulacoseira* in Verlorenvlei could represent turbidity as well as deepening of the lake because both could reduce % benthic taxa. However, wetter climates would be likely to make this particular lake more turbid as well as deeper and more dilute, as occurs now during the rainy season when silt plumes from the Verlorenvlei River cloud the lake. The lake-wide reduction of %LOI during the increase in *Aulacoseira* percentages since 700 BP supports this conclusion. Turbidity could also result from cultural eutrophication, but there was no such human influence 700 years ago when this taxon first became common. The manuscript already does address the possibility of complicating effects of eutrophication in the most recent portion of the diatom record, but we now specifically mention *Pseudostaurosirella* and *Staurosirella* in this regard as well.

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c. If shallowing accounts for the low percentages of *Aulacoseira* in the record, then conductivity should also have increased because the lake would have become a closed basin. We find no evidence of dominance by strongly brackish-tolerant taxa such as *Nitzschia punctata* or *N. frustulum* that often occur in saline tropical lakes in Africa and elsewhere (for example: Lake Chilwetse, Mozambique, and Estuario de Virillá, Peru), and the small numbers of *Thalassiosira* in the core could represent dry season conditions (hence our reluctance to rely on quantitative estimates of salinity/conductivity based on these seasonally mixed assemblages). On the other hand, high percentages of planktonic, moderately salt-tolerant *C. meneghiniana* are indeed taken to indicate more arid (evaporative) conditions in the earlier part of the record.

Authors' response to comments by Reviewer #2:

We thank Dr. Knudson for the helpful comments.

1. We are happy to cite the new paper by Knudson et al (2011) as well as that of Moy et al (2008) in our manuscript, thereby helping to broaden the global-scale perspectives on this topic.

2. We have made the suggested change in the term "cal yr" and increased the font size of the Figure 1 labels.

3. The units in the GeoB 3313-1 figure represent those in the running mean data that were kindly provided to us by Dr. Lamy, and we now mention that source in the revised caption. The reviewer is correct in pointing out our unclear explanation of the significance of the Fe intensity values, and we have now clarified this.

4. Our primary use of the LOI and CO3 time series was in helping to establish the chronology of lake-wide changes represented in the widely spaced cores; we now explain this more clearly in the manuscript.

5. As the reviewer notes, the semantic distinction between "contractions" (by which we assume the reviewer means "latitudinal narrowing" rather than contraction-around-the-

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pole which is the most common meaning of the term) and "shifts" of the westerlies is important in the case of some records. However, the Verlorenvlei record merely represents the northern fringe of the westerly storm belt and reveals little or nothing about the southern or core sectors that are better represented in higher southern latitudes. We have, however, made our choice of terms clearer in the manuscript.

6. We do not have detailed information on the hydrological balance of Verlorenvlei, but in this semi-arid environment, conditions of P-E that would be sufficiently high to encourage high percentages of dilute-indicator diatoms in the cores while also reducing %LOI lake-wide are most reasonably attributable to rainfall. Late Holocene paleotemperature estimates for Africa are rare and their accuracy is questionable, but the relatively small magnitudes of temperature variations that are inferred for the last millennium for much of the world (as well as the evidence for synchronous disturbances in the westerlies) suggests that temperature played a smaller role than precipitation in the P-E balance here.

Interactive comment on *Clim. Past Discuss.*, 7, 4375, 2011.

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