

Interactive comment on “Salinity changes in the Agulhas leakage area recorded by stable hydrogen isotopes of C₃₇ alkenones during Termination I and II” by S. Kasper et al.

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We would like to thank the editor, Dr. Gerald Ganssen, and the anonymous referees for their comments on our manuscript “Salinity changes in the Agulhas leakage area recorded by stable hydrogen isotopes of C₃₇ alkenones during Termination I and II”. Since the comments of the editor, except one, summarize the reviewers’ comments we will mainly address the reviewers’ comments.

The one comment raised by the editor:

How is it possible that salinity increases while $\delta^{18}\text{O}$ of the water remains nearly unchanged?

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To the best of our knowledge we do not state or show in our manuscript that the oxygen isotopic composition of the water remains nearly unchanged. In fact, one of our conclusions is that the salinity shift we reconstruct based on our alkenone δD record is comparable to the salinity shift estimated based on the change in the reconstructed oxygen isotopic composition of sea water by Martinez-Mendez et al. (2010). As shown in figure 2 and 3 the $\delta^{18}\text{O}_{\text{seawater}}$ shift is approximately 1 ‰ for TII and TI, although this shift is more clear in the TII records.

The main questions raised by the reviewers:

1) One of the main issues raised by the reviewers is the lengthy discussion of the temperature reconstructions while the focus of the paper is the hydrogen isotope based salinity reconstruction.

We feel, because temperature plays such an important role in salinity reconstructions based on oxygen isotope data, that we should provide solid paleo sea surface temperature information. The core investigated allows us to compare three different temperature records based on three different and independent proxies from exactly the same samples, a fairly unique situation. The Mg/Ca based temperatures are used for correcting the oxygen isotope data because both parameters are measured on the same organism and therefore reflecting the same depth habitat, growth season etc. The other two temperature proxies do, however, indicate that temperatures might have behaved differently during MIS 6 than the Mg/Ca record indicates, possibly due to other factors influencing Mg/Ca ratios such as salinity. We therefore think that presenting the most solid available evidence for changes in paleo sea surface temperatures is essential for our paleo sea surface salinity reconstructions and requires some discussion. However, since all reviewers find this discussion too long we will revise and condense the discussion on the comparison of the temperature proxies. The revised SST proxy section will then mainly focus on implications for the alkenone hydrogen isotope ratios and salinity changes.

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2) The reviewers question the choice of measuring the δD of the combined C37:2-3 alkenones rather than analyzing of C37:2 and C37:3 alkenones separately.

We did not discuss this issue in great detail in the manuscript which is perhaps why these questions were raised. Indeed, several studies have shown that it is possible to measure individual C37 alkenones and that isotopic compositions differ between isomers (D'Andrea et al., 2007; Schwab and Sachs, 2009). However, Van der Meer et al. (2013) recently showed that the hydrogen isotopic composition of the combined C37:2-3 alkenone is reflecting a more primary signal, i.e. water δD and salinity, without biosynthetic effects related to the synthesis of the C37:3 alkenone from the C37:2 alkenone (Rontani et al., 2006). These biosynthetic effects are in turn related to temperature and thus measuring individual alkenones can impart a temperature signal on the δD of alkenones. Therefore, a combined analyses of the C37:2-3 alkenones results in a more robust δD alkenone signal for salinity reconstructions than the separate analyses of the C37:2 and C37:3 alkenones. This issue will be now addressed in detail in the next version of the manuscript.

3) The reviewers raise several questions about the discussion of the relative salinity change estimations.

The referees note that the methodology of how relative salinity changes have been derived is not described clearly enough, i.e. the information in table 3 should be described in more detail. Briefly, because the slopes of the δD and alpha salinity relationships for *E. huxleyi* and *G. oceanica* are very similar, but intercepts are quite different, we choose to calculate relative salinity changes rather than absolute salinities for both Termination I and II. For this, we calculated the average δD alkenone values for time intervals before and after Termination I and II (table 3, column 'time interval'). To estimate the global ice volume effect on sea water δD , and thus on δD alkenone, we have applied the global mean ocean $\delta^{18}O_{sw}$ record of Waelbroeck et al. (2002) for the same time intervals (table 3, column ' $\delta^{18}O_{ice}$ vol. (%)'). These oxygen isotope shifts have been transferred to an δD_{sw} shift by using a Meteoric Water Line for the Indian Ocean from

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Srivastava et al., (2010) (table 3, column ' δD_{ice} vol. (%)'). Finally, this shift in δD_{sw} has been used to correct the shift in δD alkenones due to ice volume. The relative salinity changes have then been estimated by converting the remaining δD alkenone shift for each Termination by applying the slopes of the δD alkenone – salinity relationship for *E. huxleyi* and *G. oceanica* from Schouten et al. (2006). The revised version of the manuscript will describe these calculations more clearly. Furthermore, additional key references (Sachse et al., 2012; Schwab and Sachs, 2011) for the δD alkenone quantification of salinity changes will be discussed in the article to assist readers who are not familiar with hydrogen isotopes of alkenones.

4) The referees suggest that a change in the coccolithophore assemblage can alter the δD alkenone composition.

Indeed community composition can affect the δD of alkenones as species can have different fractionations (Schouten et al., 2006; Sachse et al., 2012). However, as stated in the manuscript, this is exactly why we only use relative shifts in δD alkenones, and we only compare glacial with interglacial conditions for a single termination and we do not compare terminations with each other. Community composition changes between the two time periods will affect absolute salinity values, but not relative changes for each individual termination. Furthermore, these community changes should be relatively large to have a significant impact on the hydrogen isotopic composition of the alkenones, which did not happen throughout termination I or II. We will make this point more clear in the revised manuscript.

5) The referees would like the presented results to be integrated more into a climatic concept.

We agree that we did not discuss in detail our findings with respect to the paleoceanography of the area. In the revised version we will expand our discussion on the implications of our results. Briefly, we suggest that increased salinity during glacial periods and subsequent freshening during the glacial terminations can be explained by the effi-

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ciency of the Agulhas Leakage, the actual volume transport of water from Indian Ocean to the South Atlantic. According to Peeters et al. (2004), UK'37 SST maxima correspond to maximum Agulhas Leakage, as seen in the planktonic foraminifera Agulhas Leakage Fauna, during glacial Termination I and II. We observe enriched δ Dalkenone values, suggesting increased salinity, coinciding with reduced Agulhas Leakage during glacial stages MIS6 and MIS2/3. During the glacial Terminations, the Agulhas Leakage increases and simultaneously the alkenones become more deuterium depleted, suggesting decreasing salinities. We think that with less through-flow, the surface waters become relatively more saline and colder in the Agulhas region, including the Agulhas leakage area. With higher flow rates the surface waters will retain more of their original temperature and salinity resulting in the observed lower salinities and higher temperatures. Thus, temperature and salinity are likely decoupled in this setting. In this case heat loss is enhanced when water masses flow pole wards. Salinity, however, will be retained and during low through-flow situations in relative dry glacial periods evaporation will increase sea surface salinity while limited precipitation and river runoff will not counteract this increase sufficient. However, the absolute amount of salt that is released into the Atlantic Ocean would still increase during terminations due to the increased flow, even though the surface waters are becoming less saline, and this would still increase the Atlantic Meridional Overturning Circulation (Bard and Rickaby, 2009; Haarsma et al., 2011). The next version of this manuscript will discuss the proposed mechanism in more detail and will set the δ Dalkenone results in a more detailed paleoceanographic background.

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