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Climate of the Past
Discussions

Interactive comment on “Qualitative and quantitative reconstruction of surface water characteristics and recent hydrographic changes in the Trondheimsfjord, central Norway” *by* G. Milzer et al.

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We acknowledge the critical comments by R. Telford concerning data analysis and the derived interpretation. The main objections and doubts deal with the statistical analysis of the data set and, particularly, the application of the standard modern analogue technique (MAT).

The objective of the present manuscript is to examine the use of dinocyst assemblages in the Trondheimsfjord as proxy of recent regional climatic and environmental

changes with regard to the complex fjord hydrology. The main issue of our work deals with varying dinocyst species abundances related to ecological and climatic changes. Quantitative analyses are in this context an additional gain which is worth to consider regarding the interpretation of the assemblages, and is discussed and presented in the last part of the manuscript (section 4.4. illustrated by figures 9 and 10).

The method MAT was successfully developed for the reconstruction of sea-surface parameters in open ocean conditions for most of the existing set of marine microfossils (e.g., Imbrie and Kipp, 1971; Hutson, 1977; Birks, 1995; Maslin et al., 1995; Pflauman et al., 1996; Waelbroeck et al., 1998; Crosta et al., 1998; Kucera et al., 2005; Telford and Birks, 2011; Guiot and de Vernal, 2007), as well as for the reconstruction of continental climate conditions using pollen (e.g. Guiot, 1990). For dinocysts, the method keeps being developed and improved since more than 15 years (e.g. Guiot and de Vernal, 2007, 2011a and b; de Vernal et al., 2000, 2001, 2005, 2006; Radi and de Vernal, 2004; Bonnet et al., 2012…). By applying the method on the observed data set we rely on the basic principle and several previous tests on the methodic aspects discussed in e.g. Guiot and de Vernal, (2007, 2011a and b). The reconstruction of the sea-surface parameters in the Trondheimsfjord is thus not meant as an examination of the MAT method itself but as an initial test of the reliability of the estimated values based on dinocyst assemblages in this environment using transfer functions. However, the opportunity of comparing the estimated values with instrumental measurements in the fjord provides insight into the quality and the reliability of the reconstructions. We are aware that this quantitative exercise has strong limitations regarding the reconstructed environmental parameters (arbitrary selected with the database construction, (see also point 3 below) and the time interval targeted) but this is a (needed) step towards further (paleo)- oceanographical communities. As suggested by Telford, we will moderate the argument “a solid basis for the future investigation of Holocene paleoclimate and paleoceanographic variability.” Additionally, we would be enthusiastic about the idea to test our data with the tools developed by R. Telford, if he agrees to be part of this test.

In the following, please find the detailed responses we can propose to R. Telford for the specific problems he underlines:

1. The first point raised by R. Telford is that "…MAT gives biased estimates of the root mean squared error of prediction (RMSEP) if the observations are not evenly distributed along the environmental gradient (Telford and Birks, 2011a). In under-sampled portions of the gradient, the uncertainty can be much larger than the RMSEP as there are few available analogues. Conversely, in over-sampled portions of the gradient, the uncertainty can be smaller than the RMSEP. How much of a problem this is will depend on which part the gradient was reconstructed."

Figure 1 illustrates the question of the environmental gradients and their potential limitations for the SSTs and SSSs in winter (JFM) and summer (JAS)in the present case. The figure displays the logarithmic distribution of the ratio between the original hydrographical data (from the WOA atlas) and the reconstructed values using MAT (derived from the dinocyst 1207 database when testing the database itself using the leave-one-out technique), plotted along the seasonal SST / SSS ranges included in the n=1207 database (winter and summer). The plot describes the RMSEP consideration for both SST and SSS. The figure shows that the estimated values are close to the extracted values of the WOA ATLAS. Conversely, the large scattering of the data in the lower ranges of SSTs and SSSs illustrate the artifacts raised by R. Telford and indicate a limited confidence interval. This observation is due to MAT itself and most likely to the scattering in the existing modern data for these specific environments (e.g. high interannual variability). We additionally marked the ranges of the modern SSSs and SSTs monitored at three different mooring stations in the Trondheimfjord at 10m water depth (see table 1) by vertical boxes, blue for winter and pink for summer. The ranges of the measured SSTs and SSSs are in good agreement with the obtained reconstructions (see figure 9 in the manuscript) and confirm the statistical soundness of the calculations.

2. "The second issue mentioned by R. Telford is the risk of spatial autocorrelation within

the modern dinocyst calibration data set, and the question why we did not include the results of the surface sediment samples from the Trondheimsfjord (Milzer et al.,2013) in the modern database. "

The dataset used for calibration encompasses several analogous sample sites from the northern and southern Atlantic and Pacific region and from the Arctic (see Radi and de Vernal, 2008) in order to minimize the risk of spatial autocorrelation. Still, in our case the risk of spatial autocorrelation might be enhanced. The locations of the analogues sites found in our reconstructions are spread across the southern Norwegian Sea, the North Sea, the North Atlantic region close to the Icelandic shelf, the Hudson Bay and the St. Lawrence Estuary. The risk of autocorrelation is thus limited. By adding the data of the surface sediment samples into the modern database we would definitely increase the risk of autocorrelation. The impossibility to provide precise environmental conditions at each surface sample location in the Trondheimsfjord, however, as mentioned in the manuscript, inhibited any attempt to include the data into the modern database.

3. "The variability of several environmental variables can contaminate the reconstructions."

This is a common problem in quantitative reconstructions based on transfer functions. We also mention this uncertainty in the text pointing out that it is likely that the assemblages in the Trondheimsfjord are controlled by factors other than SST and SSS. We therefore tested the reconstructions of PP and compared the results with measured/observed primary productivity along the Norwegian coast and in other Scandinavian fjords. Still, there are further parameters affecting the assemblages which cannot be quantified either due to general difficulties in quantification or limited access to data. We will try to better clarify this issue in the revised version of the manuscript. The large uncertainties/ranges of the reconstructed value can be explained by the fact that the data presented in the tables encompass the descriptive statistics of the reconstructed minimum and maximum values found within the set of the selected analogues and the weighted average of the SST and SSS values of the five best analogues. The ranges are lower by evaluating these values independently.

4. “Why using the Wilcoxon test rather than calculating the correlation of the variability between reconstructed and instrumental data (SST and SSS).”

We decided to compare only the medians in a first step because we considered a clear correlation between the reconstructed and the instrumental values as unlikely, considering the complex hydrological setting of the fjord, as well as the influence of several environmental parameters on the dinocyst distribution (see 3.). Hence, our intention in quantitative reconstructing is basically to evaluate how far reconstructed and instrumental data differ from each other, and whether the estimated values are realistic.

5. “Why and how did we perform a NMDS on the data set and why did we apply a NMDS rather than a cluster algorithm? “

We performed the NMDS in order to identify samples with similar characteristics and to categorize them into groups using the Bray-Curtis (dis-)similarity index visualized in a 2-dimensional space as mentioned in the text. We also run a cluster algorithm which gave the same result. A cluster algorithm, however, implies a hierarchical order between the samples based on minor variability in the cyst assemblages. Although minor changes in the assemblages are of interest for further discussion, it does not serve for the illustration of similarities or dissimilarities between the different core sites. Furthermore in this restricted area a detailed discussion on site specific environmental forcing factors is hard if not impossible as the fjord hydrology is well mixed across the fjord (see 3.). Still, we will consider your suggestion and show the NMDS for further clarification, and will arrange the scale on the CA in the revised version of the manuscript.

6. “A correlation test for the relationship between the NAO and dinocyst assemblages is missing”

Your request for a statistical test of the relationship between the NAO index and the dinocyst assemblages is reasonable and will be considered in the revised version.

7. Regarding the availability of the modern database, please consider our response to L. Durantou.

8. “The description of the data handling is probably incorrect and the black polynomials look overfitted!”

Thank you again for your advice. The shown red line displays the 15 pt. running average of monthly SSTs. I will consider your advice and try the LOESS to see the difference. Ultimately, the version of Rstudio used for the analytical part is 0.97.336.

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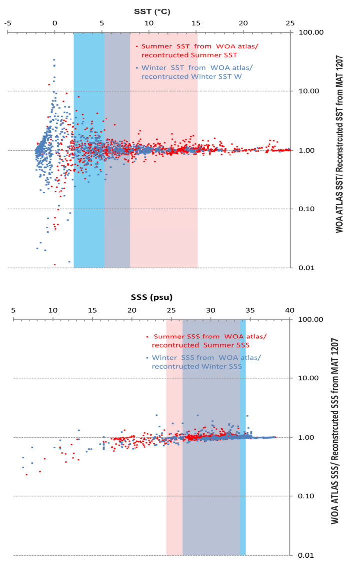

Figure 1: Logarithmic distribution of the ratio between the original hydrographical data from the WOA atlas and the reconstructed values using MAT derived from the dinocyst 1207 database. Blue and pink boxes mark the winter and summer SST and SSS ranges, respectively, measured at 10 m water depth at the mooring stations Røberg, Ytterøy and Beitstad in the Trondheimsfjord (mooring stations are illustrated in figure 1 in the manuscript).

Fig. 1.

Table 1: Instrumental measurements at the three fixed mooring stations in the Trondheimsfjord at 10 m water depth (locations are indicated in figure 1 in the manuscript)

Winter at 10 m water depth	SST (°C)		SSS (PSU)	
	min	**max**	**min**	**max**
Røberg	2.6	7.7	29.5	33.6
Ytterøy	2.1	7	28.2	34
Beitstad	2	8.2	26.6	33.6

Summer at 10 m water depth	SST (°C)		SSS (PSU)	
	min	**max**	**min**	**max**
Røberg	5.9	15.9	24.1	33.6
Ytterøy	6.2	14.7	24.7	33.4
Beitstad	6.1	14.5	25.8	32.9

Fig. 2.