**Climate
of the Past
Discussions**

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Interactive comment on "The climate in the Baltic Sea region during the last millennium" *by* S. Schimanke et al.

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Received and published: 10 July 2012

First, we would like to thank the reviewer for her/his constructive comments which will help to improve our manuscript.

Regarding the general comment about the missing volcanic forcing we would like to mention that we have been aware of this shortcoming in our setup and tried to point this out. For instance, volcanic forcing is mentioned in a crucial point of the conclusions: "Basically, three shortcomings of this study have been identified. Improved atmospheric forcing conditions including the feedbacks from volcanic activity could be crucial." Nevertheless, to make this point even clearer we will add corresponding sentences into the experimental setup as suggested in a specific point below. Moreover, we will adapt the introduction and the result section 3.1 in a new manuscript version.

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Concerning the second general comment, we agree with the reviewer that the discussion on the contribution of temperature and eutrophication for anoxic conditions can be more highlighted in a new manuscript. For this purpose, we will include a new reference (Kabel et al. 2012). This just published paper (published online 1st July 2012) comprises sediment and model studies for the Baltic Sea. Note that their results are opposite to our findings. They conclude that temperature changes are more important than eutrophication for anoxic conditions.

Particular points: 'the exact period varies between different studies. Differences between periods prior to 1850 reflect internal unforced variability and changes in external forcing as man-made contributions were small before that.' This sentence is a bit contradictory, since man-made anthropogenic forcing also counts as changes in external forcing.

The sentence will be changed to: The man-made contributions to climate change were small in these ancient times. Therefore, differences between periods prior to 1850 reflect internal unforced variability and changes in natural external forcing.

'Regional temperature variability in Europe is related to changes in the North Atlantic Oscillation (NAO) (Hurrell, 1995). Proxy data (Mann et al., 2009; Trouet et al., 2009)' 0 'and model studies (Gomez-Navarro et al., 2011) indicate that a positive NAO phase prevailed during the MCA whereas the NAO was negative during the LIA (Spangehl' When addressing the cause of past temperature changes in Europe, the state of the NAO is indeed important but it is not the whole story. When the external forcing is changing this has also a contribution to temperatures that can be stronger than the effect of the NAO. For instance, in future climates, the NAO will likely tend to become more positive, this lowering air temperatures in Greenland, but the overall evolution of Greenland temperatures will be dominated by the greenhouse gas forcing, independently of the NAO state.

The reviewer is absolutely right and we state ourselves later in the manuscript: "the

NAO index only explains some 25-50 % of the total variability on different time scales". So, the sentence was only written in a misleading way. It will be re-written to: "Apart from the direct effects of external forcing, regional temperature variability in Europe is affected by changes in the North Atlantic Oscillation (NAO) (Hurrell, 1995)."

0In the methods section a discussion on the external forcings used in the global simulation is in place see my general comment above). First, the absence of volcanic forcing should be clearly stated. Second, the amplitude of the variations in solar irradiance is also debated. The forcing used in this simulation is one choice, but not the only one that is justified.

The absence of volcanic forcing is now mentioned in the "Experimental setup", too. Moreover, we discuss the used solar amplitude by comparing with two solar studies. Basically, we changed the according section to:

"The solar variability in the models is scaled to an insolation difference between present day and the Maunder Minimum of 0.3 % (corresponds to 4W/m2), as estimated by Lean et al. (1995). Note that this is only one assumption and the discussion on the amplitude of solar variability is still ongoing (cf. Gray et al., 2010). Whereas many recent studies reveal that the amplitude was lower (e.g. only 1.3 W/m2, Krivova et al., 2007) another study shows that the amplitude could have been even higher (6 W/m2, Shapiro et al., 2011). Besides the uncertainty in the solar forcing it should be mentioned that volcanic forcing is not considered in this experimental setup. However, the role of volcanoes for climate variability is still under discussion."

'series. Applying a 20-yr running mean to the data increases the correlation coefficients to 0.66 in RCA3 and 0.52 in the proxies (Fig. 4). These results show that the model has a somewhat stronger dependence on the NAO for the winter time temperatures in Stockholm than indicated by the proxies. This holds true both on inter-annual and decadal time scales but on even longer time scales the opposite is the case as the corresponding correlation coefficient reduces to 0.59 in RCA3 while being higher, 0.68,

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in the proxies when a running 30-yr mean filter is applied.'

The differences in the correlations are not very large, and I wonder if they warrant a conclusion about the strength of the relationship between NAO and temperatures. In this case, uncertainties in the estimation of the correlation should be indicated to guarantee that the values are statistically different.

The reviewer is correct that the differences are rather small and not statistically significant. Therefore, we will lessen the strength of our statement. We will change this paragraph to: "Applying a 20yr running mean to the data increases the correlation coefficients to 0.66 in RCA3 and 0.52 in the proxies (Fig. 4). These results indicate that the model has a somewhat stronger dependence on the NAO for the winter time temperatures in Stockholm than that derived from the proxies. This holds true both on interannual and decadal time scales but on even longer time scales the opposite is the case as the corresponding correlation coefficient reduces to 0.59 in RCA3 while being higher, 0.68, in the proxies when a running 30yr mean filter is applied. The differences in correlation coefficients are, however, not statistically significant making it difficult to draw any conclusions about systematic differences between model and proxies."

'Most proxy and model studies agree that the LIA was characterised by prevailing negative NAO conditions (e.g. Luterbacher et al., 2002; Spangehl et al., 2010). For the MCA the confidence level is not that high since very few proxy data sets reach that far back in'

Here, the work of Shindell et al. Science 294,2149 (2001) should be cited

The citation will be included in the new manuscript.

'the LIA without any strong positive anomalies, the other series include several maxima with positive anomalies. Also, the strong positive NAO anomaly during the MCA in the Trouet et al. (2009) data indicates that colder than average conditions should have been prevailing in Greenland and parts of Northern Canada which is not the case

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following temperature reconstructions for that area (Ljungqvist et al., 2012). '

This conclusion is not necessarily correct. see my previous comment on the relative role of the NAO and of the external forcing on temperatures.

We agree with the reviewer that our conclusion does not have to be correct. Therefore, we will remove it in the new manuscript.

'parameters have an effect on even longer time scales (Sect. 3.1). Consistently, the SLP difference between the full MCA and LIA shows a rather weak negative NAO pattern which is mainly characterised by lower pressure in the North (Fig. 7). ' should it not read ' a rather weak positive NAO pattern '?

Absolutely! This will be changed in the revised manuscript.

'over the Baltic Sea (0.73 K). The remaining energy is consumed at least partly for the melting of sea ice. '

The discussion here is a bit confusing. Temperature is not equal energy. Higher or lower temperatures may be sustained without any change in the energy content. It all depends on the balance of energy fluxes.

Our statement was not well formulated and the reviewer is right that the reasons are more diverse and should be investigated in terms of energy fluxes. However, this is not the focus of this study. Therefore, we will remove the according sentence.

'Second, the long-term variability (50-yr average) within the observational data is larger than the difference between the modelled MCA and LIA conditions. This adds further evidence that the simulated temperature difference between the MCA and LIA is underestimated.'

This comparison is not totally fair because it related to two different time scales. The annual cycle at a certain location is certainly larger than the temperature difference between MCA and LIA. By the same token the decadal variability in the observational pe-

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riod, specially at regional scales, can be perfectly larger than the centennial timescale difference between MCA and LIA.

We are not comparing two different time-scales. All values, e.g. simulations and observations, refer to 50 years periods. We will re-write the sentence to make this clear: "Second, the long-term variability within the observational data is larger than the difference between the modelled MCA and LIA when 50-years periods are considered."

'The mean difference in salinity between RCO-MCA and RCO-LIA is 0.69 PSU' volume-averaged?

Yes, volume-averaged. The text will be changed accordingly.

References:

Kabel et al. (2012, Nature Climate Change): Impact of climate change on the Baltic Sea ecosystem over the past 1,000 years, doi 10.1038/NCLIMATE1595

Krivova et al. (2007, A&A): Reconstruction of solar total irradiance since 1700 from the surface magnetic flux, 467, 335–346, doi:10.1051/0004-6361:20066725

Shapiro et al. (2011, A&A): A new approach to the long-term reconstruction of the solar irradiance leads to large historical solar forcing, 529, A67, doi:10.1051/0004-6361/201016173

Interactive comment on Clim. Past Discuss., 8, 1369, 2012.