

Interactive comment on “Northern high-latitude climate change between the mid and late Holocene – Part 1: Proxy data evidence” by H. S. Sundqvist et al.

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We acknowledge the constructive and detailed comments given by the four referees and Eduardo Zorita. As recommended by the editor we will thoroughly revise the manuscript and carefully address all the concerns raised by the reviewers before submitting an improved manuscript to Climate of the Past.

As a response to the fundamental methodological problems pointed out in particular by referee #1, which were further underscored by the other referees, we plan to somewhat

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change the focus of the paper, such that less emphasis is given on explicit attempts to numerically combine the different types of uncertainties for different regions. We will instead extend the discussion of the availability of proxy data that can be used to estimate climate change between 6ka and 0ka and the different types of uncertainties in the various proxy records.

We will, in particular, tackle the two of the main concerns about the methodology raised by the reviewers as follows:

1) The effect of co-variance on the error estimates: Here we have two different types of co-variances; temporal and spatial co-variance. Eduardo Zorita has in his comment provided additional important information related to the problem with the temporal co-variance and showed that the autocorrelation function for 100-yr means of summer temperatures decays to zero (or statistically insignificant values) already for time lags less than a few millennia for the Fennoscandian area in one long simulation with a GCM. This suggests (but does not prove) that temporal autocorrelation can be neglected in estimates of uncertainty in temperature changes between time periods that are separated by six millennia in this area. Similar calculations can be made also for the other areas of interest in our study (N. America, Siberia, Greenland and Norwegian Sea), and this is something we would like to do. The problem with spatial covariance, however, cannot be neglected with similar ease. One way to tackle this problem can instead be to simply not estimate any overall uncertainty on the regional average changes. Rather, the uncertainties for each proxy record can be presented graphically region-by-region and be subject to deepened discussions of the size of uncertainties compared to the estimated climate changes.

2) The assumption that each uncertainty is a normally distributed stochastic variable: We agree that this assumption went too far, as for example dating uncertainty can deviate notably from a normal distribution. Nevertheless, it is of interest to obtain at least some meaningful quantitative estimate of how large the different types of uncertainties are in comparison with each other. It is also of interest to attempt to combine the dif-

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ferent errors to a 'total error' in the estimated climate change. A recent study by, Trouet et al. (2009), actually made explicit attempts to translate dating uncertainty in proxy data to uncertainty in a climate variable (in their case an NAO-index) in a manner that is very similar to our proposed approach. In the revised version of paper I, we intend to further discuss the size and the impact of the different errors separately, but we need not necessarily attempt to explicitly combine them. A practical reason for combining the errors, however, is for the cost function analysis undertaken in paper II, which requires quantified uncertainties for each proxy. We plan to study the effect of combining the different types of errors in the cost function analysis, but the result of such a study is better suited to be presented in paper II, whereas paper I can instead focus more on documenting and discussing the different sources of uncertainty.

References Trouet, V., Jan Esper, J., Graham, N.E., Baker, A., Scourse, J.D., Frank, D.C. Persistent Positive North Atlantic Oscillation Mode Dominated the Medieval Climate Anomaly, *Science* 324 (5923), 78-80.

Yours Sincerely, Hanna Sundqvist, Qiong Zhang, Anders Moberg, Karin Holmgren, Heiner Körnich and Johan Nilsson

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