Geophysical Research Abstracts
Vol. 12, EGU2010-7988, 2010
EGU General Assembly 2010
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Reconstructing temperatures from lake sediments in northern Europe: what do the biological proxies really tell us?

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Over the past two decades considerable effort has been devoted to quantitatively reconstructing temperatures from biological proxies preserved in lake sediments, via transfer functions. Such transfer functions typically consist of modern sediment samples, collected over a broad environmental gradient. Correlations between the biological communities and environmental parameters observed over these broad gradients are assumed to be equally valid temporally. The predictive ability of such spatially based transfer functions has traditionally been assessed by comparisons of measured and inferred temperatures within the calibration sets, with little validation against historical data. Although statistical techniques such as bootstrapping may improve error estimation, this approach remains partly a circular argument. This raises the question of how reliable such reconstructions are for inferring past changes in temperature?

In order to address this question, we used transfer functions to reconstruct July temperatures from diatoms and chironomids from several locations across northern Europe. The transfer functions used showed good internal calibration statistics ($r^2 = 0.66 - 0.91$). The diatom and chironomid inferred July air temperatures were compared to local observational records. As the sediment records were non-annual, all data were first smoothed using a 15 yr moving average filter. None of the five biologically-inferred temperature records were correlated with the local meteorological records. Furthermore, diatom inferred temperatures did not agree with chironomid inferred temperatures from the same cores from the same sites.

In an attempt to understand this poor performance the biological proxy data was compressed using principal component analysis (PCA), and the PCA axes compared to the local meteorological data. These analyses clearly demonstrated that July temperatures were not correlated with the biological data at these locations. Some correlations were observed between the biological proxies and autumn and spring temperatures, although this varied slightly between sites and proxies. For example, chironomid data from Iceland was most strongly correlated with temperatures in February, March and April whilst in northern Sweden, the chironomid data was most strongly correlated with temperatures in March, April and May. It is suggested that the biological data at these sites may be responding to changes in the length of the ice-free period or hydrological regimes (including snow melt), rather than temperature per se.

Our findings demonstrate the need to validate inferred temperatures against local meteorological data. Where such validation cannot be undertaken, inferred temperature reconstructions should be treated cautiously.