Modelling Temporal Uncertainty in Palaeoclimate Reconstructions

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Abstract

We present a method for reconstructing an aspect of climate over 13,000 years at Sluggan Moss, Northern Ireland. We extend the work of [1] to include calibrated radiocarbon ages. The required chronologies are obtained via a new monotone stochastic process. We also discuss the t_8 long-tailed random walk model and produce predictive climate estimates.

1. Introduction

We consider the problem of reconstructing the pre-historic climate of Western Europe from pollen data. The results have wide-ranging implications for archaeologists and climatologists, particularly those who work on general circulation models (GCMs). The statistical palaeoclimate model can be compared to GCMs to assess model fit and corroborate evidence of global warming.

The data set involved with the reconstruction contains a large number of modern data points which link together the proportions of up to 50 different pollen taxa with 3 climate proxies at 7815 locations. These data provide a picture of the pollen response to climate change through a Bayesian hierarchical model with latent spatial parameters; known as *response surfaces* [2]. Additional data are available in the form of *fossil* pollen records from lake sediments around Western Europe, dated via radiocarbon methods. A further Bayesian model estimates the fossil climate proxies over time.

[1] reconstructed climate at one of 800 locations where these data are available. We extend the work to consider data at several locations. From a statistical perspective, the problem contains aspects of: hierarchical modelling, parallel computing, transfer functions, radiocarbon interpolation of pollen fractions, fast cross-validation and methods for dealing with complex data structures. We concentrate on the model building and fitting aspect of the project.

2. Response Surfaces

The response surfaces link climate to pollen taxa. They are built via a zero-inflated multinomial distribution based upon the pollen proportions. The zero-inflation parameters and the Poisson rates from which the proportions are obtained are both modelled in three dimensional climate space. Many spatial models are possible; we will examine that of kernel convolutions of varying complexity.

The size of the response surfaces data set and the number of parameters involved (over 10,000 in [1]) is a large computational burden. Unfortunately, MCMC at present does not lend itself well to parallelisation, though attempts have been made [3]. The task is to update a multivariate latent spatial process (the response surfaces) at speed whilst taking advantage of the parallel processing power available. We use a Gaussian Markov Random Field (GMRF) approximation to the posterior to produce response surfaces without the need for MCMC.

3. Temporal climate reconstruction

We discuss two issues. Firstly, age-depth models must be used to estimate the ages of the fossil pollen sections using radiocarbon dating techniques. Second, the spatio-temporal model from which we draw samples of fossil climate for the chosen locations. [1] showed that, whilst climate variables appear smooth for the majority of the previous 10,000 years, there are periods of rapid climate change. Such a change is a necessary part of the model-building for fossil climate reconstruction. Figure 1 represents a climate reconstruction for Sluggan Moss in Northern Ireland.

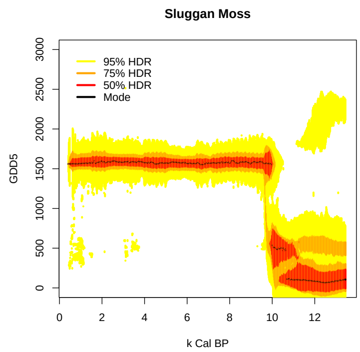

Figure 1: Highest posterior density regions for growing degree days above 5 degrees (GDD5) reconstruction at Sluggan Moss utilising full temporal uncertainty via a gridded t-process.

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4. Bibliography

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