Bayesian Palaeoclimate Reconstruction from Pollen

Andrew C. Parnell[*,1,2], James Sweeney[3], Thinh K. Doan[4], Michael Salter-Townshend[2], Judy R.M. Allen[5,] Brian Huntley[5], and John Haslett[4]

[1]School of Mathematical Sciences (Statistics), University College Dublin, Ireland
[2]Complex and Adaptive Systems Laboratory, University College Dublin, Ireland
[3]School of Mathematical Sciences, University College Cork, Ireland
[4]School of Computer Science and Statistics, Trinity College Dublin, Ireland
[5]School of Biological and Biomedical Sciences, Durham University, UK
[*]andrew.parnell@ucd.ie

We outline a model and algorithm to perform inference on the palaeoclimate and palaeoclimate volatility from pollen proxy data. We use a novel multivariate non-linear non-Gaussian state space model consisting of an observation equation linking climate to proxy data and an evolution equation driving climate change over time. The observation equation linking climate to proxy data is defined by a pre-calibrated forward model, created via a multivariate latent Gaussian process fitted via integrated nested Laplace approximation (INLA). The data for this forward model are taken from a calibration set of modern climate-pollen relationships. The evolution equation representing climate change is driven by a temporally-uncertain Normal-Inverse Gaussian Levy process, being able to capture large jumps in multivariate climate whilst remaining temporally consistent. The pre-calibrated nature of the forward model allows us to cut feedback between the observation and evolution equations and thus integrate out the state nuisance parameters whilst making minimal simplifying assumptions. A key part of this approach is the creation of mixtures of marginal data posteriors representing the information obtained about climate from each individual time point. Our approach allows for an extremely efficient MCMC algorithm, which we demonstrate with a pollen core from Lake Monticchio in south-central Italy. Lastly, we present preliminary results showing how the evolution equation can be extended to produce spatio-temporal reconstructions from across Europe using the freely available data at www.europeanpollendatabase.net.

Keywords: Palaeoclimate Reconstruction, Normal-Inverse Gaussian Process, State Space Model, Temporal Uncertainty