technische universität dortmund

fakultät statistik

Juniorprofessur Environmetrics

Implementation of a Bayesian hierarchical model for spatio-temporal climate reconstructions

Masterthesis
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12.01.2026

Short description

Bayesian hierarchical models (BHMs) possess desirable properties for estimating environmental fields from sparse and uncertain data observed at non-uniformly distributed locations. This includes the ability to integrate multiple sources of information, incorporating prior knowledge about model parameters, and rigorous uncertainty quantification. However, only few spatio-temporal BHMs have been developed and applied to real-world data. The primary goal of this project is to implement a model for spatio-temporal reconstructions of climate transitions between ice age and warm climate states with a state-of-the-art generic MCMC sampling algorithm such as rstan or pymc. This model has shown promising accuracy in a simulation study but very high sample autocorrelation in the current Metropolis-within-Gibbs MCMC implementation limits its usability. The main challenge in this re-implementation is the integration of an efficient Gaussian Markov Random Field approximation of spatial climate variations in stan/pymc. After the reimplementation, systematic testing with simulations studies, application to real-world datasets, and methodological extensions of the model are possible avenues of the project. Possible thesis topics include

- Implementation of a spatio-temporal BHM for climate reconstructions in a state-of-the-art MCMC sampling algorithm such as stan or pymc
- Testing of the spatio-temporal BHM in simulation studies
- Application of the spatio-temporal BHM to a real-world dataset

Key concepts/prerequisites

- Experience with MCMC methods and Bayesian statistics
- Experience with geostatistical methods/stochastic processes
- Programming skills in R or python
- Interest in working with spatio-temporal climate data

Key references

- Chapter 4 of Weitzel, N.: Climate field reconstructions from pollen and macrofossil syntheses using Bayesian hierarchical models. Bonn, Dissertation, Rheinische Friedrich-Wilhelms-Universität Bonn, https://nbn-resolving.org/urn:nbn:de:hbz:5-56875, 2020.
- Lindgren, F., Rue, H., and Lindström, J.: An explicit link between Gaussian fields and Gaussian Markov random fields: the stochastic partial differential equation approach: Link between Gaussian Fields and Gaussian Markov Random Fields, Journal of the Royal Statistical Society: Series B (Statistical Methodology), 73, 423–498, https://doi.org/10.1111/j.1467-9868.2011.00777.x, 2011.