Combining all the pieces together to create an efficient full Bayesian geostatistical model: The SPDE method in `Stan`

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Abstract

`Stan` is a probabilistic software used to approximate a wide variety of problems emerging in different scientific disciplines, including astronomy, ecology, biology and engineering. `Stan` also has been used to analyze statistical problems in a particular spatial domain, based on observed data in a regular/irregular grid (lattice data) or point referenced data (geostatistical).
An alternative to fit spatial models is to use the integrated nested Laplace approximation (INLA) and the stochastic partial differential equation (SPDE) approaches which are implemented in the `R-INLA` package for approximated Bayesian inference in latent Gaussian models. The computational efficiency is achieved when the SPDE method approximates a Gaussian random field by a Gaussian Markov random field using a discretization of the region of the study.
In this work, we implement a C++ routine that enables to fit spatial via `Stan` using the SPDE approach. Specifically, we use Template Model Builder (`TMB`) and perform inference using the `R` package `tmbstan` which facilitates the linkage between `TMB` and `Stan`. The use of `tmbstan` allows us perform inference in a full Bayesian framework through dynamic Hamiltonian Monte Carlo, sampling the posterior distribution of the parameters of the Gaussian random field. We apply this approximation to a fishery problem where the observations are measured in space and time with the purpose of to estimate the index of relative abundance for a fishery resource structured as metapopulation.

Reference

1. Cavieres, J., Monnahan, C. C., and Vehtari, A. (2021). Accounting for spatial dependence improves relative abundance estimates in a benthic marine species structured as a metapopulation. *Fisheries Research*, 240: 105960.