EGU2020-9154
https://doi.org/10.5194/egusphere-egu2020-9154
EGU General Assembly 2020

Bayesian uncertainty quantification of spatio-temporal trends in soil organic carbon using INLA and SPDE

Nicolas P.A. Saby[1], Thomas Opitz[2], Bifeng Hu[3], Blandine Lemercier[4], and Hocine Bourennane[3]
[1]INRAE, Infosol, Orléans, France
[2]INRAE, BioSp, Avignon, France
[3]INRAE, UR Sol, Orléans, France
[4]AgroCampus Ouest, Rennes, France

The assumption of spatial and temporal stationarity does not hold for many ecological and environmental processes. This is particularly the case for many soil processes like carbon sequestration, often driven by factors such as biological dynamics, climate change and anthropogenic influences. For better understanding and predicting such phenomena, we develop a Bayesian inference framework that combines the integrated nested Laplace approximation (INLA) with the stochastic partial differential equation approach (SPDE). We put focus on modeling complex temporal trends varying through space with an accurate assessment of uncertainties, and on spatio-temporal mapping of processes that are only partially observed.

We model observed data through a latent (i.e., unobserved) smooth process whose additive components are endowed with Gaussian process priors. We use the SPDE approach to implement flexible sparse-matrix approximations of the Matérn covariance for spatial fields. The separate specification of the spatially varying linear trend allows us to conduct component-specific statistical inferences (range and variance estimates, standard errors, confidence bounds), and to provide maps to stakeholders for time-invariant spatial patterns, spatial patterns in slopes of time trends, and the associated uncertainties. For observed data following a Gaussian distribution, we add independent measurement errors, but more general response distributions of the data can be implemented. We also include in our model covariate information on parent material, climate and seasonality.

The INLA method and its implementation in the R-INLA library provide a rich toolbox for statistical space-time modelling while sidestepping typical convergence problems arising with simulation-based techniques using Markov Chain Monte–Carlo codes for large and complex hierarchical models such as ours. Uncertainties arising in model parameters and in pointwise spatio-temporal predictions are naturally captured in the posterior distributions computed through INLA using appropriate approximation techniques, and we can communicate on them through maps of various properties. Moreover, INLA also allows for direct simulation from the estimated posterior model, such that we can conduct statistical inferences on more complex functionals of the multivariate predictive distributions by analogy with MCMC frameworks.

Soil organic carbon is a major compartment of the global carbon cycle and small variations of its level can largely impact atmospheric CO_2 concentrations. In the context of global climate change, it is important to be able to quantify and explain spatial and temporal variability of SOC in order to forecast future changes. In this work, we used this approach to study possible trends in space and time of soil carbon stock of three agricultural fields in France. Fitted models reveal significant temporal trends with strong spatial heterogeneity. The Matérn model and SPDE approach provide a flexible framework with respect to field design.