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Geoscientific Model Development Discussions

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Interactive comment on "Bayesian spatiotemporal inference of trace gas emissions using an integrated nested Laplacian approximation and Gaussian Markov random fields" *by* Luke M. Western et al.

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General comments The authors present a model for inferring spatially and temporal correlated emissions of greenhouse gases. The model is constructed following a Bayesian hierarchical framework and the Integrated Nested Laplace Approximation (INLA) method is used for making inferences. The stochastic partial differential equation (SPDE) approach is exploited with a Gaussian Markov Random Field (GMRF) representation. The main advantage of the approach presented is the computational efficiency for Bayesian inference. So it represents an alternative to MCMC methods

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Discussion paper

that tend to be slow and hard to achieve convergence in the presence of multiple parameters. The concept and ideas presented represent and contribution. However, the presentation of methods and results can be improved and sharing the codes developed would help others to use the proposed method. Please see below my specific comments and suggestions to improve the manuscript.

Specific comments Page 3: In Section 2.1 the linear model for the spatial field is briefly described and derived. This section can be improved without loss of generality by starting from equation 3 that contains all relevant quantities of interest expressed as deviations from prior mean values. In addition, the physics behind factor x or some interpretation about its connection with the measurements could be added in this section to help the reader better understand the model. Page 4, Line 2: The solution to the stochastic differential is a stationary Gaussian Field with Matern covariance structure. The fact that the process is stationary should be mentioned. Moreover, if the covariance function does not depend on the direction but just on the Euclidean distances between s_i and s_j, then it should also be mentioned that the process is isotropic. Page 5, equation 6: The indices and ranges should be explained. For instance, i=1,..,n. Does n represent the number of nodes in the mesh? Also, index j goes from 1 to 4. Does this represent the sides of the rectangular region? Page 7, Line 15: Is there any advantage regarding the computational cost or convergence for using penalized complexity priors instead of a vague prior? Pages 10-13, Section 3.2: More information about the simulation study should be included in the main text or supplementary materials. Would be nice to see the relationship between the true parameters from the simulated data and the estimated values along with their corresponding uncertainty. Also, would be interesting to complement the posterior mean estimate plots as function of time with analogous plots showing some measure of the uncertainty on the estimates (e.g. SE or credible set). Last, the value of this manuscript would be greatly improved if the R code used for the numerical experiment could be shared. However, if the complexity and scale of the problem makes this option not feasible, then at least a toy example to illustrate the concept would be useful. Pages 15-16: The discussion section could mention some limitations of the method. First, the stationarity assumption may not be suitable when modelling some environmental phenomena. Particularly in atmospheric phenomena it may inappropriate to assume that the spatial correlation is the same throughout the domain as topographical variables (e.g. mountains, lakes, etc.) might have an influence on the spatial dependence. Second, INLA method relies on the assumption of approximate multivariate normality of the posterior linear predictors.

Technical corrections Page 4, Line 19: provided instead of providing. Page 6, Line 12: consider rephrasing: "... which means that the spatiotemporal precision matrix can be expressed using a Kronecker product as follows...", and delete Line 15. Page 6, Line 17: burden instead of size. Page 6, Line 19: consider rephrasing: "...constant over a three-month period..." Page 6, Line 19-20: Later in the text you use four three-month periods, not three. Page 7, Line 10: consider rephrasing "...for the spatial precision matrix Q(\theta)^{-1}, are ..." Page 16, Line 13: rephrase to "...correlation structure may vary in space."

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