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Spatio-temporal evolution modeling of environmental and natural phenomena

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Abstract

This short paper introduces the special issue containing six selected papers coming from the International Workshop on Spatio-temporal Modeling (METMA V) held in Santiago de Compostela (Spain), from 30 June to 2 July 2010.

Keywords: Anisotropy; Average temperatures; Spatial clustering; Functional processes; Integrated nested Laplace approximation; Spatial variability; Spatio-temporal modeling; Two-stage Bayesian approach; Wavelet analysis.

1. Introduction

In recent years, spatio-temporal modeling has become one of the most interesting and, at the same time, challenging research areas of natural and environmental sciences. The relevant literature is growing fast and along directions that range from theoretical and methodological developments to real world applications. Spatio-temporal systems modeling involves the synthesis of a rich interdisciplinary body of knowledge for which it is necessary to establish a solid theoretical foundation and a science-based methodology with both researchers and practitioners in mind.

In this context, the biannual International Workshop on Spatio-temporal Modeling (METMA) has reached its fifth edition, and has been held in Santiago de Compostela (Spain), from 30 June to 2 July 2010. With the purpose of promoting the development and application of spatio-temporal statistical methods in different fields related to environmental sciences, METMA V contributions gathered the latest advances in statistical methodology illustrated with environmental data. With more than 150 participants from 10 different countries, senior and junior researches, who attended the invited and contributed sessions (with a no-parallel session system, which favored the exchange of ideas and experiences), this international work-

shop has become a cornerstone in the worldwide meetings related to this topic, while keeping the maximum number of participants within a very reasonable size.

We would like to express our gratitude and thanks to all the members of the local organizing and scientific committee. We also would like to thank all the participants for their contributions to the spatio-temporal field in its wide sense: geostatistics, point processes, and lattice data. Two Special Issues have arisen from this workshop, one published in *Environmetrics*, and the other one here in *Journal of Environmental Statistics*. The complete list of papers presented at the workshop and any particular information are posted at: http://eio.usc.es/pub/metma/index.php?lang=en.

In light of the above considerations, the articles of this Special Issue have been carefully selected to present a variety of conceptual frameworks, powerful methods and comprehensive techniques that address a number of interesting problems in environmental, health, social and medical sciences. Bayesian hierarchical spatio-temporal models are considered in Saez *et al.* and Jin *et al.* Integrated nested Laplace approximations within the Bayesian approach for replicated data in time are used in Illian *et al.* Wavelet analysis for detecting and comparing trends, investigating spatial heterogeneity and periods of significant variability in non-stationary environmental time series is considered in Franco-Villoria *et al.* Anisotropy and spatial clustering effects are analyzed by Kelly. Finally, a functional approach for spatio-temporal strong dependence processes is presented by Frias and Ruiz-Medina.

Assessing the spatial and temporal variability of temperatures, through describing the mean function as well as the spatio-temporal covariance structure of maximum and minimum daily temperature data is the core aim in Saez *et al.* in their paper entitled *Space-time interpolation of daily air temperatures*. The authors propose an estimation of the long-term trend of maximum and minimum temperatures, model the spatio-temporal variability of temperatures, and interpolate the spatial temperatures at any given time. Long-term trend, annual harmonics and winds are considered as explanatory variables of the mean function. The parameters associated with these variables are allowed to vary between stations and within each year. The temporal autocorrelation is controlled through ARMA models, and spatio-temporal models are built as Bayesian hierarchical models with two stages following the integrated nested place Laplace approximation (INLA) for Bayesian inference. The spatial parameters are also allowed to vary with time.

A statistical method for modeling ground-level ozone concentration in a given region is developed and presented in Jin *et al.*, where an environmental network design problem is also explored. By applying hierarchical Bayesian spatio-temporal modeling, a conditional predictive distribution over a set of grid points is obtained. In terms of an entropy criterion, the environmental network design problem is solved using the obtained predictive distributions. Model evaluation is also provided.

As it is known and has become popular in the very recent years, integrated nested Laplace approximation (INLA) provides a fast and exact approach to fitting complex latent Gaussian models which comprise many statistical models in a Bayesian context. Illian *et al.* discuss how a joint log Gaussian Cox process model may be fitted to independent replicated point patterns. They illustrate the approach by fitting a model to data on the locations of muskoxen herds in Zackenberg valley, Northeast Greenland and by detailing how this model is specified within the R-interface R-INLA.

A wavelet analysis is presented in Franco-Villoria *et al.* as a possible method for detecting

and comparing trends, investigating spatial heterogeneity and periods of significant variability in non-stationary environmental time series. Their results confirm a difference in river flow maxima between regions due to changes in the seasonal patterns that may be linked to external climatic drivers, including the North Atlantic Oscillation and the Atlantic Multidecadal Oscillation. Such influences (which act on several time scales, the principal one being annual) are not constant and vary both temporally and spatially, with a possible catchment size effect, highlighting the importance of assessing flood risk at a regional level.

A practical problem on examining the spatial association of bovine TB in cattle herds using data from Ireland is presented in Kelly. Badgers, a protected species, have been implicated in the spread of the disease in cattle. Current disease control policies include reactive culling (in response to TB outbreaks) of badgers in the index and neighbouring farms. The author accounts for possible anisotropy. Changes in the spatial association over two time periods are also examined. The results have direct implications for establishing scale and direction in reactive culling. They are also important regarding the evaluation of vaccines for badgers and cattle.

Filtering and parameter estimation are addressed in the context of spatio-temporal strong dependence processes. A functional parametric observation model is fitted to the spectral sample information. Large dimensional spectral data sets, displaying high local singularity, are then processed in this functional setting. Thresholding techniques are first applied for removing noise generated from measurement spectrometer device. Spatio-temporal long-range dependence model fitting is then achieved by applying linear regression in the log-wavelet domain.

We hope the reader finds this selection of papers in the spatial and spatio-temporal context useful, comprehensive and inspiring. In that case, the METMA V atmosphere will have been honestly translated into this volume. We finally would like to thank the authors for their outstanding research contributions and, in particular, Prof. Rick Schoenberg (Editor-in-Chief of Journal of Environmental Statistics) for his encouragement and support in preparing this Special Issue.

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