Hierarchical Bayesian Spatio-Temporal Conway-Maxwell Poisson Models with Dynamic Dispersion

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Modeling spatio-temporal count processes is often a straightforward endeavor. However, in many real-world applications the complexity and high-dimensionality of the data and/or process do not allow for routine model specification. For example, spatio-temporal count data often exhibit temporally-varying over/underdispersion within the spatial domain. In order to accommodate such structure, while quantifying different sources of uncertainty, we propose a Bayesian spatio-temporal Conway-Maxwell Poisson (CMP) model with dynamic dispersion. Motivated by the problem of predicting migratory bird settling patterns, we propose a threshold vector-autoregressive model for the CMP intensity parameter that allows for regime switching based on climate conditions. Additionally, to reduce the inherent high-dimensionality of the underlying process, we consider nonlinear dimension reduction through kernel principal component analysis. Finally, we demonstrate the effectiveness of our approach through out-of-sample one-year-ahead prediction of waterfowl migratory patterns across the United States and Canada. The proposed approach is of independent interest and illustrates the potential benefits of dynamic dispersion in terms of superior forecasting.

Key Words: Count data, Empirical orthogonal functions, Kernel principal component analysis, Threshold vector autoregressive model