Overview of computational methods, data assimilation, and change-of-support for spatial-temporal data

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Outline

Potential topics for Winter 2017

1. Computational methods
2. Change of support
3. Data assimilation
4. Other

Computation

Objective: increase computational efficiency or tractability for massive data sets and large numbers of parameters

Some general approaches

- Model reformulation
- Dimension reduction
- Approximations
- Algorithms

Computation

Dimension Reduction

- Basis function representations, e.g.,
  - spectral decompositions
  - empirical orthogonal functions
  - fixed-rank kriging
- Process convolutions
- Lattice and nearest-neighbor methods (Gaussian Markov random fields, CAR models)
- Covariance tapering (sparse approximation to covariance)

Computation

Approximations

- Approximate or composite likelihoods
- Integrated nested Laplace approximations (INLA) allow fast approximation of posterior distributions
- Data subsampling (e.g., M-posterior approximation)

Computation

Algorithms

Some examples:

- Stochastic gradient methods (e.g., Hamiltonion Monte Carlo - joint proposals with high acceptance)
- Block updating in MCMC
- Fast Fourier transform (spectral methods)
- Cholesky decomposition (matrix operations)
- EM algorithm
- Paralellization

Change of Support

Problem: Data and processes of interest are at different spatial or temporal resolutions or alignments.

Observe at	Inference at	Examples
Point	Point	Kriging
Point	Line	Contouring (upscaling)
Point	Area	Block kriging (upscaling)
Area	Point	'Ecological' inference (downscaling)
Area	Area	Misaligned regions (up- or downscaling)

(modified from Gotway and Young 2002 and Craigmile notes)

Change of Support Example

from Gelfand and Carlin 2001

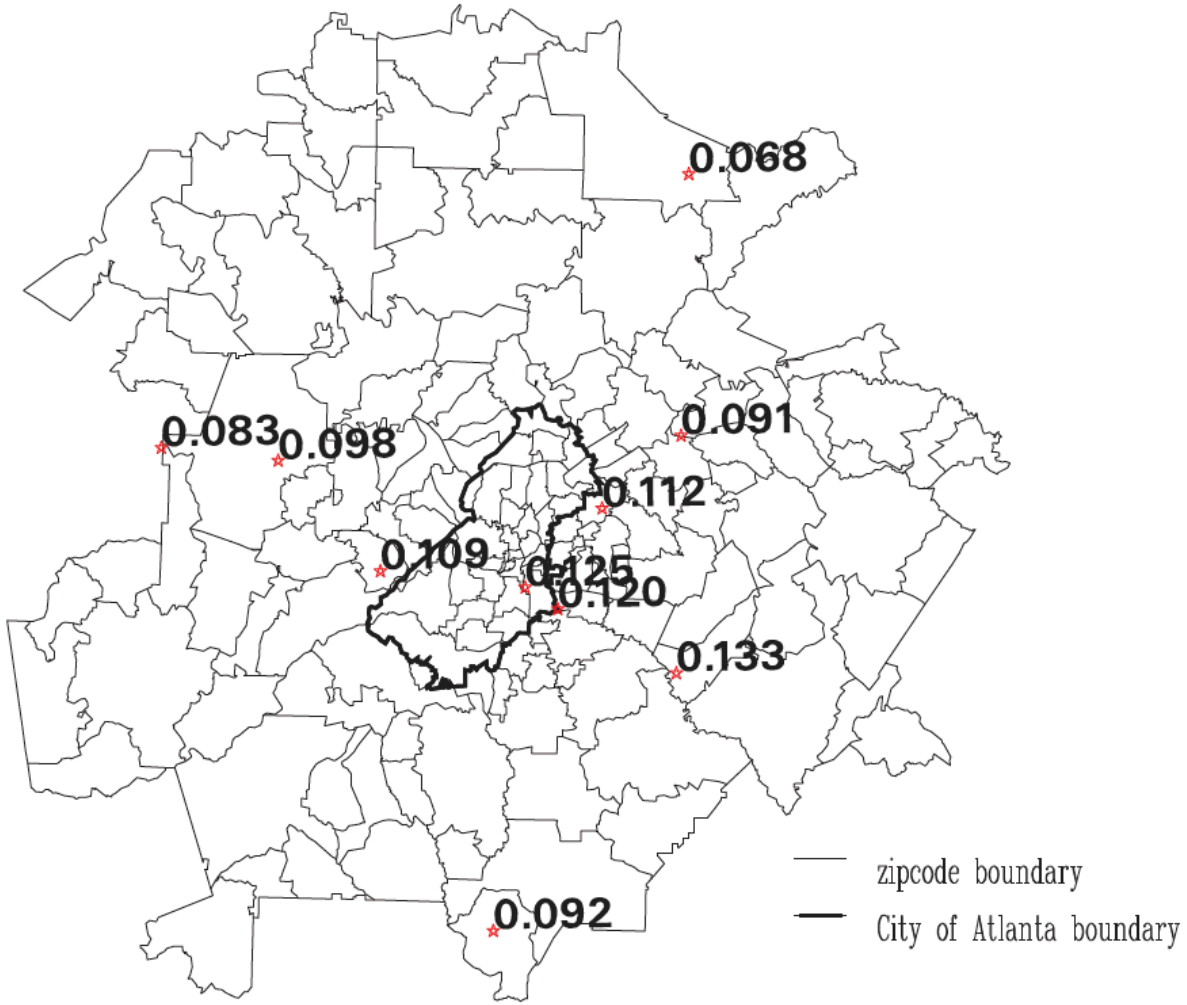

Figure 1: Zip code boundaries in the Atlanta metropolitan area and eight-hour maximum ozone levels (ppm) at the 10 monitoring sites for July 15, 1995.

Data assimilation

Objective: combine predictions from numerical simulation models with observed data to make improved predictions that account for uncertainty.

Examples:

- Combine real-time weather observation data with weather prediction model output to improve forecasts
- Use air quality monitoring data with output from numerical air quality model to predict particulate matter

Data assimilation

Some example methods:

- Ensemble models
- Fusion modeling
- Bayesian hierarchical models