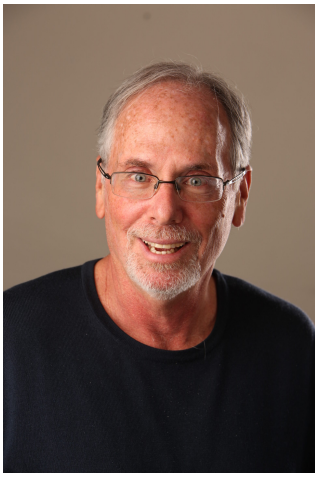
Short course on Bayesian analysis of spatially referenced data with applications in ecology and environmental exposure

Presenter: Prof. Alan E. Gelfand



Bio: Prof. Gelfand is J.B. Duke Professor of Statistics at the Department of Statistical Science at Duke University. Prof. Gelfand is one of the most accomplished and influential contemporary statisticians. He has authored more than 280 scholarly articles and is considered a leading expert in Bayesian computation and spatial statistics.

Background: It is recommended that attendees have background knowledge in statistical inference, i.e. likelihood, point and interval estimation, hypothesis testing, likelihood ratio tests and knowledge of generalized linear models.

Lecture 1: Bayesian inference, a modern perspective I

- How does Bayes theorem become an inference paradigm
- Principles of Bayesian inference
  - estimation, prediction, testing, specifying priors
- Model adequacy and model selection
  - in-sample vs. out-of-sample, validation/cross-validation, AIC, BIC, DIC, empirical coverage, predictive mean square error, rank probability scores, model averaging

Lecture 2: Bayesian inference, a modern perspective II

- Bayesian data analysis
  - Hierarchical modeling, random effects, missing data, latent variables, dynamic (state space) models; what is the problem of Bayesian computation?
- Basics of Bayesian computation
  - Monte Carlo sampling; Gibbs sampling and Markov chain Monte Carlo, Metropolis Adjusted Langevin, INLA, ABC

Lecture 3: Spatial modeling and data analysis I

- Introduction
  - Types of spatial data, examples
- Basics of point-referenced data models
  - Spatial processes (Gaussian processes), Stationarity and isotropy, variograms; spatial exploratory data analysis (EDA); kriging

Lecture 4: Spatial modeling and data analysis II

- Basics of areal data models
  - Markov random fields, conditionally autoregressive models, smoothing and shrinkage, autoregressive models for binary data and for count data.

Lecture 5: Spatial modeling and data analysis III

- Hierarchical modeling for univariate spatial data
  - geostatistical/spatial process models, spatial GLMs, areal data modelling, misalignment
- Illustrative data analyses: scallops (point-referenced, Gaussian), lip cancer (areal, Poisson)

Lecture 6: Species Distribution Models

- What are species distribution models?
- Types of data
  - presence/absence data, presence-only data, abundance data
- Features of species distribution models
  - prevalence, diversity, turnover
- Joint species distribution models
- Hierarchical modeling for species distributions
- Application: Cape Floristic Region in South Africa

Lecture 7: Environmental Exposure Modelling

- Environmental contaminants (primarily ozone and particulate matter)
- Space and space-time specifications
- Data fusion
  - station data, satellite data, computer model output
- Species of particulate matter
- Preferential sampling
- Application: U.S. monitoring network data.

Lecture 8: Spatial Event Time Problems

- Time to event data
  - time to bud burst (first flowering) of various tree species across space
  - time to wildfire events and inter-arrival times between wildfires across space
- Spatial survival analysis
- Exceedances
  - renewal processes and alternating renewal processes
- Species of particulate matter
- Preferential sampling
- Applications: Japanese cherry blossoms and wildfires in South Africa

Suggested readings: Bayesian inference

1. Bayesian Data Analysis, A. Gelman et al. ISBN 10: 158488388X / ISBN 13:9781584883883 (three editions)

2. Bayesian Methods for Data Analysis, Third Edition, Bradley P. Carlin Thomas A. Louis, CRC Press

3. Doing Bayesian Data Analysis:A Tutorial with R, JAGS, and Stan. 2nd Edition. John K. Kruschke, 2014. Academic Press / Elsevier. ISBN: 9780124058880

4. The BUGS Book: A Practical Introduction to Bayesian Analysis (Chapman & Hall/CRC Texts in Statistical Science) by D. Lunn; C. Jackson; N. Best; A. Thomas; D. Spiegelhalter

5. For INLA: http://www.math.ntnu.no/ hrue/r-inla.org/doc/Intro/Intro.pdf and the website of Havard Rue (Trondheim)

6. For dynamic models: A. Pole, M. West, J. Harrison, Applied Bayesian Forecasting and Time Series Analysis, 1994, CRC Press

Suggested readings: Spatial modeling and data analysis

1. Hierarchical Modeling and Analysis for Spatial Data (Chapman & Hall/CRC Monographs on Statistics & Applied Probability) by S. Banerjee, B. P. Carlin, A. E. Gelfand, 2014

2. Statistics for Spatio-Temporal Data, N. Cressie, C. K. Wikle, 2011, J.Wiley and Sons

3. Spatio-temporal Design: Advances in Efficient Data Acquisition, J. Mateu (Editor), W. G. Muller (Editor), J. Wiley and Sons, ISBN: 978-0-470-97429-2, 2012

4. Handbook of Spatial Statistics, A. E. Gelfand, P. Diggle, P. Guttorp, M. Fuentes, 2010, CRC Press

5. Model-based Geostatistics, P. Diggle, P. J. Ribeiro, 2007, Springer

6. Statistical Analysis and Modelling of Spatial Point Patterns, J. Illian, A. Penttinen, H. Stoyan, D. Stoyan, 2008, John Wiley & Sons