Statistical Modeling and Inference for Climate Applications

Jon Hobbs
Jet Propulsion Laboratory, California Institute of Technology
Jonathan.M.Hobbs@jpl.nasa.gov

1. Bayesian Inference

   - Hierarchical Model

$$\begin{aligned} \text{Data} &= Y(\mathbf{s}_i, t) \\ \text{Process} &= \alpha(\mathbf{s}_i, t) \\ \text{Parameters} &= \boldsymbol{\theta} \end{aligned}$$

$$\begin{aligned} [\text{Data}, \text{Process}, \text{Parameters}] = &[\text{Data}|\text{Process}, \text{Parameters}] \\ &\times [\text{Process}|\text{Parameters}] \\ &\times [\text{Parameters}] \end{aligned}$$

   - Posterior Distribution

$$[\boldsymbol{\theta}|\mathbf{Y}] \propto \int [\mathbf{Y}|\boldsymbol{\alpha}, \boldsymbol{\theta}]\ [\boldsymbol{\alpha}|\boldsymbol{\theta}]\ [\boldsymbol{\theta}]\ d\boldsymbol{\alpha}$$

2. Spatial Models
   Model the joint distribution for the spatial field $\mathbf{Y}_t$

   - Covariance model
     Model $Cov(Y(\mathbf{s}_i, t), Y(\mathbf{s}_j, t))$ as a function of spatial distance
   - Spatial random effects
     Model $Y(\mathbf{s}_i, t)$ as a linear combination of a low-dimensional random vector and spatial basis functions.
   - Conditionally-specified model
     Specify conditional distributions given neighboring values

$$Y(\mathbf{s}_i, t)|\mathbf{y}_t(N_i)$$

References

Berliner, L. M. (2003). Physical-statistical modeling in geophysics. *Journal of Geophysical Research*, *108*. doi: 10.1029/2002JD002865

Besag, J. (1974). Spatial interaction and the statistical analysis of lattice systems. *Journal of the Royal Statistical Society, Series B*, *36*, 192–236.

Cressie, N. (2018). Mission CO_2ntrol: a statistical scientist's role in remote sensing of atmospheric carbon dioxide. *Journal of the American Statistical Association*, *113*(521), 152–168. doi: 10.1080/01621459.2017.1419136

Cressie, N., & Johannesson, G. (2008). Fixed rank kriging for very large spatial data sets. *Journal of the Royal Statistical Society, Series B*, *70*, 208–226.

Cressie, N., & Wikle, C. K. (2011). *Statistics for spatio-temporal data*. Hoboken, NJ: John Wiley & Sons, Inc.

Gelman, A., Carlin, J. B., Stern, H. S., Dunson, D. B., Vehtari, A., & Rubin, D. B. (2013). *Bayesian data analysis* (Third ed.). Boca Raton, FL: Chapman & Hall/CRC.

Heaton, M. J., Datta, A., Finley, A. O., Furrer, R., Guinness, J., Guhaniyogi, R., ... Zammit-Mangion, A. (2018). A case study competition among methods for analyzing large spatial data. *Journal of Agricultural, Biological, and Environmental Statistics*. doi: 10.1007/s13253-018-00348-w

Wikle, C. K., & Berliner, L. M. (2005). Combining information across spatial scales. *Technometrics*, *47*, 80–91.

Wikle, C. K., & Berliner, L. M. (2007). A Bayesian tutorial for data assimilation. *Physica D: Nonlinear Phenomena*, *230*, 1-16.