Bocconi Summer School on Advanced Statistics and Probability

Villa del Grumello, Como, Italy
Statistical science for understanding climate and the Earth system
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July 8 - 18, 2024

Schedule

Each day will include two or three morning lectures with some hands-on and group examples. Afternoons will be more substantial data analysis challenges, some mathematical challenges, "show and tell" by the class, and a short closing vignette or reprise at the end of the day.

Module 0 Introduction and setup	Monday (July 8)
Module 1 Climate	Tuesday/ Wednesday (July 9, 10)
Module 2 Geostatistics	Thursday/Friday (July 11, 12)
Module 3 Big Spatial Data	Monday (July 15)
Module 4 Bayesian Spatial Models	Tuesday/Wednesday (July 16-17)
Module 00 *Coda*	Thursday (July 18)

Students should have R, R Studio, and the R package, `fields` installed on their laptop before the first day of class. Please contact Doug Nychka (`nychka@mines.edu`) if there are problems. We will have time on the first day too to work out any difficulties.

Module 1 The Climate System, the Human Component, and Data Science

Physical Science	
	Past and current climate
	Trends and events
	What is changing, why, and how do we know
Earth System Models	
	Multi-model ensembles
	Initial condition ensembles
	Perturbed parameter ensembles
Societal Impacts	
	The risk framework
	Economic impacts
Scenarios	
	Narratives and quantitative elements
	(Shared Socio-Economic Pathways)
	Integrated Assessment Models
	(Representative Concentration Pathways)
	Future projections

Activities:

Trends in temperature and rainfall
Spatial coherence of climate fields
Repeat analysis for GCM output for historical and single forcing experiments
Pattern scaling and local climate sensitivity.

Reading Material:

- IPCC AR6, Working Group 1, Summary for Policy Makers, (hiips://wwwipccch/report/ar6/wg1/chapter/summary-for-policymakers/)
- IPCC AR6, The synthesis report, Summary for Policy Makers, (hiips://wwwipccch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_SPM.pdf),
- IPCC AR6, Working Group 1, Chapter 1 (hiips://wwwipccch/report/ar6/wg1/chapter/chapter-1/)

Module 2 A normal world

		Textbook sections
Multivariate Gaussian		2.7
	Covariance and positive definite	2.4
	Decorrelating Data	
	precision vs. covariance	
Gaussian Processes		
	Definition and properties	3.1 -3.3
	Covariance Functions	3.3-3.7
	Generating GP realizations	4.1
	GP and dependence	3.4
Prediction		
	Gaussian linear model	5.1
	GP prediction	5.2
Kriging		
	Prediction and covariates	5.2.3
	A Derivation of Kriging	
	Uncertainty estimates	5.2.5
	Conditional simulation	5.2.7
	Maximum Likelihood	6.1

Activities:

- Generating random functions and computing the covariance.
- Decorrelating climate output.
- The magical circulant embedding algorithm.
- Curve fitting using Kriging
- Bootstrap of covariance parameters
- Spatial analysis of observational data
- Regridding and conditional simulation

Reading Material:

Sections in the outline refer to the draft textbook *Spatial Data Science*, Bandyopadhyay, Kleiber, Nychka (2024).
See `spatialdatascienceComoSchool.pdf` in the class folder.

- To review linear regression models see 2.1 through 2.5 !

- To review matrix algebra see Appendix A.1

Module 3 Smoothers and big data

Splines and Smoothers	
	Kernel methods
	Penalized least squares
	What is a spline?
Basis function models	
	L2 difference penalty in 1D
	Derivation of SAR and its Precision
	Sparse linear algebra
	Computational efficiency and tuning
Open research	
	Computation using Deep Learning

Activities:

- Kernel smoothing and smoothing matrices
- Timing sparse matrix methods
- Dissecting the LatticeKrig model
- Deep learning, simulation, and the lazy data scientist!

Reading Material:

- See `LatticeKrigJCGS.pdf` for a version of a basis function model that works for large data sets.
- See `FastCovariancesNeuralNetworks.pdf` for an application of neural networks for fast parameter estimation.

Module 4 Bayesian methods

	Topics and textbook sections	
Bayesian Methods		
	A Bayesian spatial model	8.3
	Sampling using MCMC	
Bayesian Hierarchical Models		
	Formulation	
	Benefits and computational issues	
Open research		
	Hybrid L^2, L^1 smoothing	

Activities:

- Gibbs sampling a spatial model
- Adding layers to a hierarchy
- Atmospheric CO2 and ice cores
- Using `SPBayes`

Reading Material:

- See `BayesianRegridding.pdf` for an application of Bayesian models to regional climate models and solar radiation.