CEE 696: Data Assimilation in Civil and Environmental Engineering and Earth Science

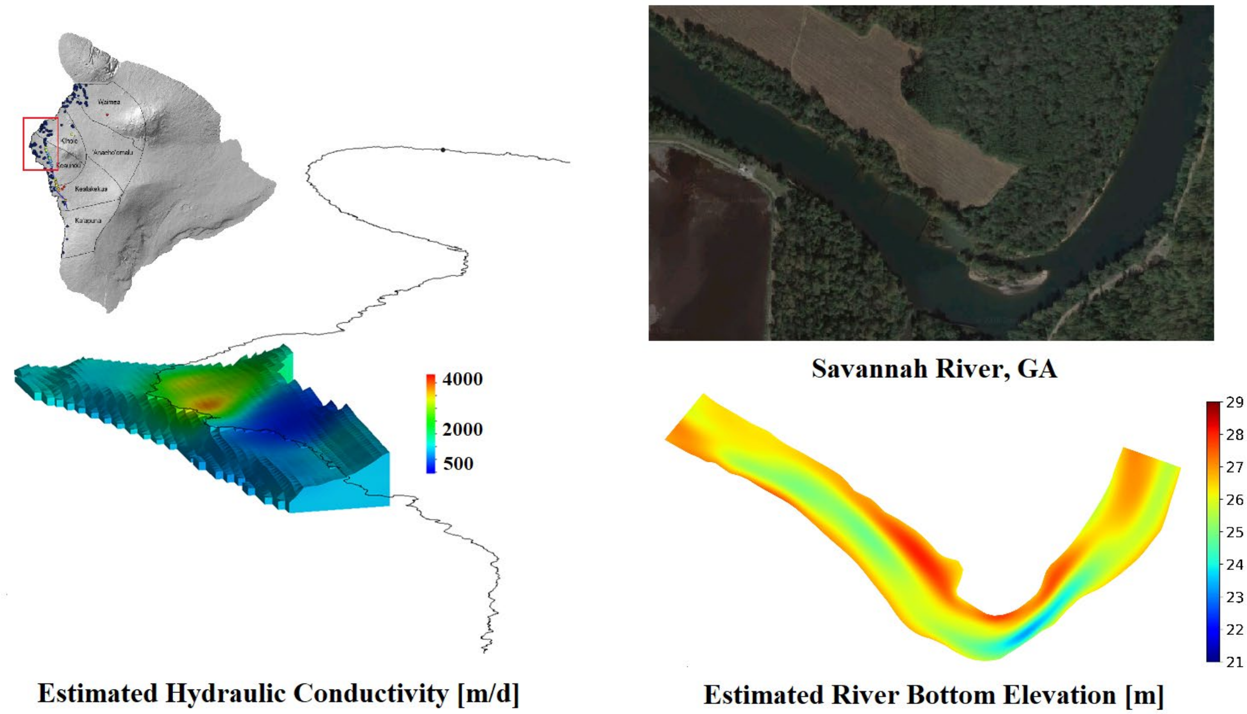

Figure. Inverse modeling using well data for hydraulic conductivity estimation of Keauhou Basal Aquifer, Big Island (left), Surface Velocity data assimilation for the bathymetry estimation of Savannah River, GA (right)

Course Description:

This course covers both statistical and computational aspects of inverse modeling (*i.e.*, batch data inversion) and data assimilation (*i.e.*, real-time forecast). Students will focus on stochastic methods for the solution of inverse problem and data assimilation that are 1) algebraically underdetermined, *i.e,* the number of data is much smaller than the number of unknowns, and 2) ill-posed, *i.e.,* sensitive to data. "Stochastic" means that we recognize that the data do not allow us to arrive at a unique solution so we assign weights to plausible solutions within a probabilistic framework. Emphasis is on Bayesian methods that, in addition to using data, incorporate information about structure such as spatial/temporal continuity and smoothness. The class will then discuss methods for real-time processing of sequentially obtained data, as in monitoring applications.

The material presented in the class as a set of useful algorithms to solve inverse modeling and data assimilation problems. To just use such algorithms and produce some useful results, it is not essential to have much specialized background, other than some knowledge of probability theory and linear algebra. However, to get a better understanding of the applicability of these methods and the meaning of the results, one must have some background in statistical and computational methods. For this reason, we start this class with a review of basic concepts from probability and statistics, stochastic analysis, and Bayesian inference. The class is taught in a way that can accommodate both those who are primarily interested in using tools and those who want to get a deeper understanding and advance the state of the art. The class is intended for post-MS students.

Instructor: Dr. Jonghyun Harry Lee (jonghyun.harry.lee@hawaii.edu)

Website: https://www2.hawaii.edu/~jonghyun/classes/S21/CEE696/

Textbook: A course on imaging with incomplete data by Peter Kitanidis (a copy of the manuscript will be distributed to students during the class). Additional class notes, slides, and reference materials will be posted on the class website.

Class Meetings: TBA

Prerequisites: Probability Theory, Linear algebra/Optimization Basics, Script Programming Languages (Python/Matlab/Julia)

Assignments: homework will be assigned once a week or every two weeks

Grading: 80% assignments, 20% final project presentation

Tentative outline of lecture topics:

1. Intro to inverse problem
2. Probability theory
3. Linear inverse problem
4. Linear algebra view of the inverse solution
5. Conditional simulation
6. The inverse problem as filtering problem
7. Fast Linear Algebra with FFT and Kronecker Product
8. Intro to recursive filtering; Kalman filter
9. Nonlinear inverse problem and adjoint method
10. Extended Kalman filter
11. Ensemble and spectral covariance matrix approximation
12. Advance Topics: Nonlinear Filtering, H-matrices & Fast Multipole Methods, and so on if time is allowed.