SIO230 Introduction to Inverse Theory
Syllabus

Instructor: Cathy Constable (cconstable@ucsd.edu, x43183)

4 units, 3 hour meeting/week, homework, S/U grades permitted.

Prerequisites: graduate standing or consent of instructor; familiarity with topics covered in SIO223A.

The class will be taught in Fall 2016, and on Tuesdays and Thursday afternoons 1:30-2:50pm.

Description: This class deals with geophysical inverse theory. The key factor that makes inverse theory different from simple parameter estimation (the classical statistical problem) is that the number of observations available is finite, while the unknown model requires infinitely many variables for its full description. Thus in practical inverse problems (those based on real as opposed to idealized data) there is always ambiguity in the model. Finding a particular model solution involves a choice from an infinitely large collection of alternative solutions. The approach taken in the class is to apply mathematical optimization to select the simplest models. This avoids the introduction of unnecessary exciting features. To discover reliable properties of the earth, independent of any particular model, we must calculate upper and lower bounds on functionals that represent those properties. The utility of stochastic methods for identifying a range of acceptable models will also be discussed.

The class will begin with a broad overview of inversion and some practical applications, followed by a synopsis of some necessary mathematical ideas. There will be homework, which will be posted on the class website: http://igppweb.ucsd.edu/∼cathy/Classes/SIO230/index.html Other information will also be posted here. The course is largely based on is Geophysical Inverse Theory, Princeton University Press, 1994, by R. L. Parker. Many students find the text by Aster et al (2013) a useful supplement. Further books for background reading on mathematical and statistical matters are listed below.

Topics included:

(1) Mathematical Precursors

(2) Introduction to functional analysis up to the Projection Theorem for Hilbert spaces.

(3) Linear inverse problems with exact and uncertain data; model construction; regularization as the minimization of model complexity.

(4) Numerical methods for practical solutions, including QR and SVD factorizations.

(5) Resolution: Backus-Gilbert theory.

(6) Inference: bounding functionals in Hilbert and other Banach spaces; ideal body theory.

(7) Other constraints; linear and quadratic programming.

(9) Nonlinear inverse problems solved by linearization; Fréchet and Gateaux derivatives.

(10) Iterative optimization: Backus-Gilbert creeping; Occam's method.

(11) Stochastic inversion, transdimensional inversion, and other topics

Recommended Reading

Aster, R.C., B. Borchers, & C.H. Thurber, 2013. *Parameter Estimation and Inverse Problems, Second Edition*. Academic Press, Oxford, UK.

Parker, R.L., 1994. *Geophysical Inverse Theory*. Princeton University Press, Princeton, New Jersey.

Tarantola, A., 2005. *Inverse Problem Theory and Methods for Model Parameter Estimation*. SIAM, Philadelphia, Pensylvania.

Strang, G., 1980. *Linear Algebra and its Applications*. Academic Press, New York.

Strang, G., 1986. *Introduction to Applied Mathematics*. Wellesley-Cambridge Press, Wellesley, Mass..

Dekking, F.M., C. Kraaikamp, H.P. Lopuhaä, L.E. Meester, 2005. *A Modern Introduction to Probability and Statistics: Understanding Why and How*. Springer, London.