Instructor: John Harlim
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Office Hours: By appointment

Time and Place: Tu Th, 11.45-1, SAS 1218

Text: Course notes will be distributed
(see a draft of Chapter 1 in http://www4.ncsu.edu/~jharlim/paper/toc_intro.pdf).

Prerequisites: This is a self-contained course and is designed for first year math/stats/eng grad or advanced undergrad students with some familiarity of Linear Algebra (MA405), Advanced Calculus (MA425), Probability Theory (MA421), and Differential Equations (MA401).

Topics: Given noisy observations from nature, filtering is the process of finding the best statistical estimate of the true signal. Filtering consists of a two-step predictor-corrector scheme that adjusts a prior forecast distribution to be more consistent with the current observations. The revised probability distribution is then fed into the model as an initial condition for the future time prediction. This approach of generating initial conditions is also known as data assimilation. Important examples of applications include numerical weather and climate predictions. In this particular application, the demand for operationally practical filtering methods escalates as the model resolution is significantly increased. In the coupled atmosphere-ocean system, the current operational models for weather and climate predictions are discretized in space and time and the effects of unresolved processes are parameterized according to various recipes. The resulting dynamics of such models are extremely unstable and chaotic with several billion degrees of freedom. They typically have many spatiotemporal scales, rough turbulent energy spectra in the solutions near the mesh scale, and a very large dimensional state space.

In this survey course, I will cover recently developed mathematical strategies for filtering turbulent signals. These reduced filtering strategies, developed by the instructor and his collaborators, blend ideas from several topics in applied mathematics, including: classical stability analysis for PDE’s and their finite difference approximations; Fourier series; suitable Kalman and particle filters; stochastic models for turbulent systems and turbulent-diffusion; information theory; statistical aspects of chaotic dynamical systems; model errors and stochastic parameterization. I will also cover the state-of-the-art ensemble based approaches advocated by leading experts in the atmospheric/ocean sciences community.

Grading: Course grade will be determined by a project. This project can be in the form of reading a recent related journal article, developing or reproducing some filtering techniques on a simple test-bed model, and presenting a short report to the class. Students will be provided with a step-by-step “cook-book” and are encouraged to numerically simulate these (or other) filtering techniques on a simple test-bed model.