METR 6803

Advanced topics in data assimilation: Ensemble Kalman filter techniques

Instructor: Dr. Xuguang Wang (xuguang.wang@ou.edu)

Office hours: Wednesday 9:30am – 12:00am, NWC 5341

When and where: Tuesday and Thursday 10:00-11:15am, NWC 5720

Prerequisites: MATH 3113 (ODE), 4163 (PDE), and 3333 (linear algebra); ENGR 3723 (numerical methods) or equivalent or permission of instructor. Programming experience is useful. Not limited to Meteorology students.

Reference texts:

- R. Daley, 1995: *Atmospheric Data Analysis.*
- E. Kalnay, 2002: *Atmospheric Modeling, Data Assimilation and Predictability*.
- J. Lewis, S. Lakshmivarahan, and S. K. Dhall, 2006: *Dynamic data assimilation: A least square approach*.
- Selected journal articles.

Grading policy:

- In-class exams (35%): Mid-term exam (15%), Final exam (20%)
- Homework assignments (45%)
- In-class presentation (20%)

Objectives:

The course is designed to introduce students to the world of ensemble Kalman filter data assimilation techniques (EnKF), an advanced data assimilation method that has been recently explored extensively in Meteorology and has started to be explored in other fields such as Ecology and Hydrology. The students will learn the most popular EnKF techniques through lectures and hands-on project assignments. The students will not only learn various EnKF techniques but also develop their skills in scientific thinking and synthesis, written and oral communication and programming throughout the course.

Tentative Syllabus:

- Introduction to data assimilation (1 lecture)
- Mathematical preparation: matrix algebra (2 lectures)
- Least square and Bayesian contexts (3 lectures)
  Homework Assignment 1
- Brief review of objective analysis, OI, 3DVAR and 4DVAR (1 lecture)
- Classic Kalman filter and Extended Kalman filter (3 lectures)

- Introduction to Ensemble Kalman filter (1 lecture)
  Homework Assignment 2
  In-class mid-term exam
- Ensemble Kalman filter with perturbed observations (2 lectures)
- Ensemble square root filter (2 lectures)
- Local Ensemble Transform Kalman filter (2 lectures)
  Homework Assignment 3
- Common problems and treatments in ensemble Kalman filters (4 lectures)
  Homework Assignment 4
- Ensemble smoother (1 lecture)
- Hybrid ensemble-variational method (1 lecture)
  Homework Assignment 5
- Applications of EnKFs (6-8 lectures by the instructor and *student power point presentations of assigned papers*) on atmosphere, land surface, oceanography, hydrology, ecology, etc.
- Preparing final exam (1 lecture)
- Guest seminar lecture (1 lecture)
  Final exam

Homework assignments:

- Prove equivalence of solutions from least square and Bayesian frameworks using 1D/2D example.
- Provide prior ensemble and observations, and use EnKF to obtain posterior ensemble.
- Choose one of EnKFs, run the filters and describe what the filter does. Lorenz 96 model with one EnKF programmed in Fortran will be provided. Students are welcome to use their own numerical models in their research.
- Choose one of EnKFs, examine sensitivity to inflation and localization parameters.
- Compare any two of the EnKFs or examine effect of model errors.

In-class presentations:

Student will select one topic of the specific applications of EnKFs, review it, write a short paper and do an in-class presentation.