Special Topics in Data Assimilation

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Description:

Data assimilation in oceanic and atmospheric circulation models, as well as in other simple models is discussed. Topics include function fitting through the least-squares approximation, nudging, penalty functionals, representers, optimization, the initialization problem, 'weak' and 'strong' constraints, error covariance, and Kalman filters. This course is based heavily in computational methods for optimizing model predictions, and uses simple toy models that the students are expected to understand and alter.

Course Outline:

Week 1:
Class: Review of statistics. Least squares approximation and function fitting.
Reading: Daley *Atmospheric Data Analysis,* Chapter 2
Lab: Introduction to the python programing language.

Week 2:
Class: Optimal interpolation and forward model development.
Reading: Daley *Atmospheric Data Analysis,* Chapter 4
Lab: Linear algebra functions and techniques using `numpy`

Week 3:
Class: Toy ocean/atmosphere model
Reading: Bennett *Inverse Modeling of the Ocean and Atmosphere*, Chapters 1&2
Lab: Basic forward numerical modeling of the transport equation and the Lorenz models.

Week 4-6:
Class: Adjoints, Lagrange multipliers, penalty functionals, representers, 'weak' and 'strong' constraints.
Lab: Toy ocean forward, tangent-linear, and adjoint models based on the transport and KvD equations.

Week 7-9:
Class: Practical optimization methods, estimating error covariance, data nudging, the Kalman filter.
Reading: Whitaker and Hamill (2002) *Monthly Weather Review*
Lab: Kalman filters and ensemble Kalman filters for the transport, KvD equations, and Lorenz models.

Week 10-13:
Class: Literature review – examples of data assimilation
    (E.g., modern adjoint model development, particle filters, Bayesian statistics)
Reading: Paper choices based on student interests.
Lab: Building an adjoint model from source code.

Week 14-15:
Class: Student project discussion

Learning outcomes:

Students will learn to fit functions using least squares regression, interpolate observations using optimal interpolation (OI, 3Dvar), create and use a simple adjoint model (4Dvar), create and use an ensemble Kalman filter (EnKF).

Prerequisites:

Knowledge of basic statistics and programing skills (we will use python, but FORTRAN or MATLAB skills will be sufficient). OCNG 657, STAT 601, or instructor permission.

Grading:

Homework will be assigned for each of the broad topics, and will primarily involve computer program modification discussed in the lab. Homework will account for 40% of your final grade. Also, students will be expected to contribute to, and occasionally lead, discussions of scientific papers, accounting for 20% of your grade. A research project, for example consisting of a small program implementing some data assimilation method, with an accompanying in class demonstration, will account for the remaining 40% of your grade. The grading scale is 90-100% = A, 80-89% = B, 70-79% = C, etc.

Text:

There will be no text for this class. Excerpts will be taken from the literature and these two books:

- *Atmospheric Data Analysis*, by Roger Daley
- *Inverse Modeling of the Ocean and Atmosphere*, by Andrew F. Bennett

Attendances:

Excused absences will be based on Student Rule 7 (http://student-rules.tamu.edu/rule07). Please inform me before any planned absences, and I will try to be accommodating.

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