SIOC 224 (Spring 2020)

Numerical Modeling of the Climate System

Instructor: Ian Eisenman (eisenman@ucsd.edu).

Lectures and assignments *(tentative and evolving)*

Zoom info for joining lectures: here (access restricted to UCSD community).

Lecture schedule:

- Mon 3/30 (01): Intro (course overview, finite differencing, Forward Euler & Implicit Euler & Leapfrog methods). Reading: CRB 1.9-1.10.
- Wed 4/01 (02): ODEs (truncation error, dimensionless form). Reading: CRB 1.11.
- Mon 4/06 (03): ODEs (numerical instability, higher time derivatives, stability of oscillatory motion with Forward Euler). Reading: CRB 2.6-2.7.
- Wed 4/08 (04): ODEs (predictor-corrector test step, semi-implicit Euler, semi-implicit leapfrog, Runge-Kutta). Reading: CRB 2.6, 2.8-2.9.
- Mon 4/13 (05): PDEs (finite differencing with PDEs, semidiscrete formulation, periodic boundary conditions). Reading: CRB 5.3.
- Wed 4/15 (06): EBMs (idealized models of global climate). Reading: North et al. (1981).
- Mon 4/20 (07): more PDEs (diffusion equation numerical stability and accuracy). Reading: CRB 5.4.
- Wed 4/22 (08): more PDEs (diffusion equation with varied time stepping, finite volume method). Reading: CRB 5.5-5.6, 3.9.
- Mon 4/27 (09): more PDEs (advection equation numerical stability, Robert-Asselin filter, summary of PDE methods). Reading: CRB 6.4, 10.6; Durran 2.4.2.
- Wed 4/29 (10): TBA.
- Mon 5/04 (11): Assimilation (adjoint models and state estimation).
- Wed 5/06 (12): Statistics (probabilities and Kalman filtering *guest lecture by Mati Morzfeld*).
- Mon 5/11 (13): GCMs (governing equations in atmosphere/ocean GCMs). Reading: CRB 11.4, 19.4, 20.6; Holton 13.1, 13.2, 13.5.
- Wed 5/13 (14): GCM workshop (analyzing internal climate variability in CESM-LE model output).
- Mon 5/18 (15): High-res (high-resolution GCM simulations *guest lecture by Julie McClean*).
- Wed 5/20 (16): Hierarchy (atmospheric models with a range of complexities *guest lecture by Casey Wall*).
- Mon 5/25: *No class (Memorial Day)*
- Wed 5/27 (17): EBM workshop (dealing with numerical issues in idealized model research).
- Mon 6/01 (18): TBA.
- Wed 6/03 (19): Student project presentations.

Recorded lecture videos: Lectures will be recorded and made available to students who are unable to attend in real-time at the link here (access restricted to UCSD community).

Lecture notes: (0) Intro, (1) ODEs, (2) PDEs, (3) EBMs, (4) more PDEs, (5) assimilation, (6) GCMs

Homework assignments:

- HW-1 *(due 4/8)* (solution)
- HW-2 *(due 4/15)*

Course description

Lectures: Lectures will be given remotely on Mondays and Wednesdays at 12:30-1:50 Pacific Time at the Zoom link mentioned above. All lectures will be recorded and made available through this website for those who are not able to join them live.

Access: The course lecture videos, lecture notes, homework assignment and solutions, etc, will be posted on this website and made accessible only to the UCSD community (through VPN or from IP addresses that are added for individual students).

Synopsis: This course will provide an introduction to the methods used in numerical models of the ocean and atmosphere. The course is aimed at a broad range of SIO graduate students and is intended to serve as a first course in numerical methods. A range of numerical methods will be introduced in the context of a series of example problems: a large-amplitude pendulum, dye flowing in a pipe, and a simple diffusive energy balance model of the atmosphere and climate. This will be followed by an overview of the equations represented in general circulation models (GCMs) of the atmosphere and ocean and the additional numerical methods that are used to solve them. Adjoint methods for state estimation, analysis of GCM output, and other topics will be covered in the latter part of the course. Each student will be asked to do a project during the course in which they numerically solve a system of equations describing a geophysical problem of their choice (some suggested problems will also be provided).

(Zoom) Office Hours: I will informally hold office hours over Zoom immediately after each class. Students are welcome to email me anytime with questions or to setup a Zoom meeting.

Grading: 60% homework, 40% final project. This course can be taken for letter grade or pass/not pass. Auditors are also welcome.

Homework: There will be periodic homework assignments. Homework assignments may be turned in one class later than they are due (grace period). Homework will be graded on a ✓+, ✓, ✓- basis. Students are encouraged to work together on homework exercises (using Zoom or similar software); each student should turn in only his or her own work. Homework should be turned in via email as a PDF attachment, and I'll grade it and return it as an annotated PDF via email.

Final project: Each student will be asked to do a project during the course in which they numerically solve a system of equations describing a geophysical problem of their choice (some problems will be suggested). Each student will give a presentation of their project to the rest of the class near the end of the course and submit a written report.

Textbook: All readings will be available for download from the course website. Readings will include sections from *Introduction to Geophysical Fluid Dynamics* by Benoit Cushman-Roisin and Jean-Marie Beckers (2011, listed as "CRB" in schedule below), online here (individual sections from library) or here (all sections concatenated into single 140MB file).