**SIOC 224 (Spring 2022)**

# Numerical Modeling of the Climate System

**Instructor:** Ian Eisenman, (office) Nierenberg Hall 223, (email) eisenman@ucsd.edu.

**Course website:** Canvas.

## Lecture schedule *(evolving)*

- Mon 3/28 (01): Intro (course overview, finite differencing, Forward Euler & Implicit Euler & Leapfrog methods). Reading: Cushman-Roisin & Beckers (CRB) sections 1.9-1.10.
- Wed 3/30: *No class (instructor on travel)*
- Mon 4/04 (02): ODEs (truncation error, dimensionless form). Reading: CRB 1.11.
- Wed 4/06 (03): ODEs (numerical instability, higher time derivatives, predictor-corrector test step, semi-implicit Euler). Reading: CRB 2.6-2.7.
- **Fri** 4/08 (04) *(make-up class at 12:30 in Eckart 227)*: ODEs (semi-implicit leapfrog, Runge-Kutta). Reading: CRB 2.6, 2.8-2.9.
- Mon 4/11 (05): PDEs (finite differencing with PDEs, semidiscrete formulation, periodic boundary conditions). Reading: CRB 5.3.
- Wed 4/13 (06): EBMs (idealized models of global climate). Reading: North et al. (1981).
- Mon 4/18 (07): more PDEs (von Neumann method for diffusion equation). Reading: CRB 5.4.
- Wed 4/20 (08): more PDEs (diffusion equation numerical stability and accuracy). Reading: CRB 5.4.
- Mon 4/25 (09): more PDEs (diffusion equation with varied time stepping, advection equation numerical stability, summary of PDE methods). Reading: CRB 5.5-5.6, 6.4.
- Wed 4/27 (10): Statistics (random variables, Bayes' rule, and Kalman filtering to connect models with observations *guest lecture by Matti Morzfeld*).
- Mon 5/02 (11): Data assimilation (4D-VAR, linearized adjoint models). Optional reading: Bannister (2007).
- Wed 5/04 (12): Reanalysis (ocean reanalysis products *guest lecture by Matt Mazloff*).
- Mon 5/09 (13): GCM intro (governing equations and numerical methods in atmosphere/ocean GCMs). Optional reading: CRB 11.4, 19.4, 20.6; Holton 13.1, 13.2, 13.5.
- Wed 5/11 (14): GCM history (history of GCMs and related early GCM papers *guest lecture by Emma Beer and Matt Luongo*).
- Mon 5/16 (15): GCM coupling (coupling of GCM components and related research approaches *guest lecture by Emma Beer and Matt Luongo*).
- Wed 5/18 (16): High-res GCMs (high-resolution GCM simulations *guest lecture by Julie McClean*).
- Mon 5/23 (17): GCM output workshop (analyzing internal climate variability in CESM-LE model output).
- Wed 5/25 (18): Student project presentations.
- Mon 5/30: *No class (Memorial Day)*
- Wed 6/01 (19): Student project presentations (cont'd).
- Fri 6/03 *(extra class at 12:30 in Nierenberg Hall 400)*: Student project presentations (cont'd).

## Course description

**Date, time, location:** Mondays and Wednesdays, 12:30-1:50, in person in Spiess 330. Lectures will also be broadcast on zoom (you can access the zoom link and recorded lectures via the Canvas website).

**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).

**Office Hours:** I will hold office hours immediately after each class. Students are welcome to email me anytime with questions or to setup a meeting. Students are also welcome to stop by my office anytime, but I recommend checking beforehand to make sure I am in.

**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); let me know if you need more time on an assignment. Students are encouraged to work together on homework exercises; each student should turn in only his or her own work. Please do not consult homeworks or solutions from previous years.

**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), [individual chapter PDFs or all chapters in single PDF].