MAR 572
Fall 2024
Geophysical Simulation
MoWe 5:00pm - 6:20pm
ENDEVOR HALL 168 WESTCAMPUS

Instructor: Prof. Marat Khairoutdinov
Office hours: by email appt
Email: marat.khairoutdinov@stonybrook.edu
Credit: 3 hours

Despite confusing title, this class is about how to simulate atmosphere or ocean flows using models. It is an introduction to numerical methods of solving differential and general nonlinear equations, which are common to modeling the Earth atmosphere and land. If you are using or planning to use atmospheric models, you need to know the fundamental core topics that this class covers to better understand the limitations of the numerical modeling of atmosphere, and possibly improve those models or even design your own model in the future!

The course does not strictly follow any textbook. In fact, the field of computational fluid dynamics and related techniques is too broad to be covered in a single textbook. Therefore, it is important to take class notes. However, here is a short list of recommended books that should be consulted for some additional details and also generally are good to have as reference:

Zikanov, O, 2010: Essential Computational Fluid Dynamics. Wiley and Sons. 302pp.
Durran, D. R., 1999: Numerical methods for wave equations in geophysical fluid dynamics. Springer, 465 pp.
Fletcher, C. A. J., 1991: Computational Techniques for Fluid Dynamics, Vol. 1. 2nd ed. Springer-Verlag, 401 pp.
Daley, R. 1991: Atmospheric data analysis. Cambridge University Press, 455pp

Grading:
50% for 2 exams and 20% for a hands-on project, 30% for home assignments. No final exam.
All assignments/exams are graded using 100 score as the perfect score.
Grade conversion: A: >90, B+: 86-90, B: 76-85, C+: 70-75, C: <70

Special Note:
Hands-on experience is the best way to learn numerical methods. Homework will involve writing simple programs and plotting the results. You will need to have access to computers with programming and graphing software. Knowledge of high-level compiled (e.g., Fortran) or scripting (e.g., Python) computer languages is required for this course. Fortran is strongly encouraged as it is the main programming language in atmospheric sciences (as it typically produces the fastest code). So, coding homework in Fortran is a good way to practice one. For plotting results Python is actually a much simpler way. Homework can be discussed with other students; however, each student is expected to write/code the solutions independently.

The following topics are generally covered. Some of the topics can be replaced/changed.

Fundamentals of Finite-Difference Schemes

Numerical solution of nonlinear equations. Definitions of consistence, convergence, and stability; First and second order derivatives; Construction of higher order approximations.

Methods for Initial-Value Problems of Linear Partial Differential Equations

Linear computational stability analysis; Classification and canonical forms; Basic numerical schemes for advection and diffusion equations**;** Upstream and downstream biased schemes; Time-integration schemes; Time-splitting and directional splitting schemes; Implicit and explicit schemes; Numerical diffusion and dispersion; Extension to multiple dimensions; Grid systems.

Methods for Nonlinear Initial-Value Problems

Fourier representation of discrete fields; Nonlinear interaction and instability; Methods to eliminate nonlinear instability; Construction of conservation schemes; Monotonic and positive definite schemes; Anelastic vs compressible equations; Barotropic vorticity model; the Arakawa Jacobian; Basic concepts of spectral methods; Semi-Lagrangian and finite-volume methods

Methods to Solve Elliptic Equations

Fourier method; Relaxation methods; Multi-grid methods.

Models

Dynamical cores of contemporary climate models; Parameterization of convection; Sub-grid scale turbulence; Surface fluxes over land and water; Parameterization of vegetation and soil; Cloud Microphysics Schemes

Americans with Disabilities Act
If you have a physical, psychological, medical, or learning disability that may impact your course work, please contact the Student Accessibility Support Center, Stony Brook Union Suite 107, (631) 632-6748, or at sasc@stonybrook.edu. They will determine with you what accommodations are necessary and appropriate. All information and documentation is confidential.

Academic Integrity Statement
Each student must pursue his or her academic goals honestly and be personally accountable for all submitted work. Representing another person's work as your own is always wrong. Any suspected instance of academic dishonesty will be reported to the Academic Judiciary. For more comprehensive information on academic integrity, including categories of academic dishonesty, please refer to the academic judiciary website at http://www.stonybrook.edu/uaa/academicjudiciary/
Adopted by the Undergraduate Council September 12, 2006

Critical Incident Management
Stony Brook University expects students to respect the rights, privileges, and property of other people. Faculty are required to report to the Office of Student Conduct and Community Standards any disruptive behavior that interrupts their ability to teach, compromises the safety of the learning environment, or inhibits students' ability to learn. Faculty in the HSC Schools and the School of Medicine are required to follow their school-specific procedures. Further information about most academic matters can be found in the Undergraduate Bulletin, the Undergraduate Class Schedule, and the Faculty-Employee Handbook.