Numerical Methods and Modeling (ATM 562)
Fall Semester 2024
Class Number: 9670 (3 credits)

Lecture: Tuesday & Thursday 9:00-10:20 in ETEC 482
https://www.atmos.albany.edu/daes/atmclasses/atm562

Instructor:

Professor Ryan Torn
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Office hours: Wednesday 1:00-2:00, and by appointment

Course Description:

This is a hands-on course in numerical modeling, focusing on understanding the components of numerical models and how they work. Lectures will cover atmospheric dynamics and thermodynamics in the context of numerical modeling; and numerical methods and their accuracy, consistency and stability.

Course Objective:

This course will describe the components of a numerical weather prediction model, including how to solve partial differential equations using numerical methods, how to deal with unresolved features, model initialization, ensemble forecasting, along with emerging AI/ML models.

Prerequisites:

ATM 500 or consent of the instructor.

Recommended Text:

Numerical Methods for Wave Equations in Geophysical Fluid Dynamics by D. R. Durran
Parameterization Schemes: Keys to Understanding Numerical Weather Prediction Models by D. J. Stensrud

Supplementary reading:

Atmospheric Modeling, Data Assimilation and Predictability, by E. Kalnay
Cloud Dynamics, by R. A. Houze Jr.
A First Course in Atmospheric Numerical Modeling, by A. J. DeCaria, G. E. Van Knowe

Course Requirements:

2 Homework assignments: 20%
2 Programming assignments: 20% each
1 In-class exam: 20%
Independent Project: 20%
Grading: A-E

Course Format:

Students are expected to attend each lecture. In addition, lectures will be recorded when possible and posted to Brightspace, so students can review lectures afterward. **Watching lectures online is not a substitute for attending lecture. If students start to watch lectures online instead of attending, I will discontinue recording.** Absences are unavoidable; therefore, in those situations, students are expected to view the lecture recording (Brightspace keeps track of who views each lecture).

Course Communication:

The primary communication method for the course will be through messages through Brightspace. These messages will be archived on the course page and will automatically send to your UAlbany email address. All lecture materials and assignments will be placed on the course Brightspace page. Students may communicate with each other through the Brightspace discussion system. I will answer all emails within 24 h of receipt, except on weekends.

Accommodating Disabilities Policy:

Reasonable accommodations will be provided for students with documented physical, sensory, systemic, cognitive, learning and/or psychiatric disabilities. If you believe you have a disability/disabilities requiring accommodation in this class, please notify Disability Access and Inclusion Student Services (CC 137, 442-5501, daiss@albany.edu). Upon verification and after the registration process is complete, the DAISS will provide you with a letter that informs the course instructor that you are a student with a disability registered with the DAISS and list the recommended reasonable accommodations.

Religious Observance:

Students must notify the instructor of any lectures and assignment due dates that conflict with recognized religious observances (https://www.albany.edu/registrar/academic-calendar/religious-observances) well in advance. The instructor will work with the student to provide an alternative arrangement.

Academic Integrity:

Although students can work together, all homework and lab assignments must be completed independently. Homework and lab assignments that are substantially similar to other students will be given a zero for that assignment. Copying from other students on exams may result in a zero for that work and referral for disciplinary action under the University's policy on academic integrity (https://www.albany.edu/undergraduate_bulletin/regulations.html). Every student has the responsibility to become familiar with the standards of academic integrity at the University. Claims of ignorance, unintentional error, or personal or academic pressures cannot be excuses for violation of academic integrity.

Course Outline:

1. Introduction

- Challenges of NWP
- Review of basic equations of motion

2. Numerical Methods for ODE and PDEs

   - Accuracy, stability, convergence
   - Time-stepping algorithms
   - Advection and diffusion equations
   - Horizontal meshes
   - Advanced time and space methods (Finite Volume, Semi-Lagrangian)

3. Parameterization Schemes

   - Cloud microphysics
   - Cumulus convection
   - Turbulent mixing (i.e., PBL)
   - Surface layer and land surface model
   - Radiation

4. AI/ML Methods

   - Infusion of AI/ML into NWP systems
   - Data-Driven NWP models (e.g., Pangu, GraphCast, AIFS)

5. Initialization

   - Data assimilation basics
   - Operational Schemes
   - Ensemble Systems