ATM 562 - Numerical methods and modeling
Fall 2018

Instructor: Prof. Robert Fovell

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Office hours: Whenever my door is open
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Class home page: `http://www.atmos.albany.edu/facstaff/rfovell/ATM562`
Slack channel: `http://atm562.slack.com` (Ask to join)

Credit: 3 hours
Prerequisites: ATM 500 or consent
Class meetings: MW 4:15-5:35 PM in BB 213

Required text: None. Course notes will be posted on class home page.
Useful references: Markowski and Richardson, *Mesoscale Meteorology in Midlatitudes*; Houze, *Cloud Dynamics*; Stensrud, *Parameterization Schemes*; Durran, *Numerical Methods for Fluid Dynamics: With Applications to Geophysics.*

Overview: This is a hands-on course in numerical modeling, focusing on understanding 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. The principal modeling task will be to develop a two-dimensional "cloud model" and apply it to interesting phenomena. The course is taught from the perspective of mesoscale atmospheric convection, but the tools acquired and lessons learned are generally applicable to a wide range of atmospheric and oceanic phenomena on a variety of temporal and spatial scales. Prerequisite: ATM 500 or consent of instructor.

Grading: Model tasks (40%), Exam(s) (20%), Final project (30%), Class participation (10%).

General course outline (subject to modification):

- Introduction.

  Theory: Review of basic dynamics, Taylor series and other tools. (Chapter 1)

  Application: Program simple 1D wave equation. (Model Task 0)

- Basics.

  Theory: Model equations and waves. (Chapter 2)

  Application: Compute model base state, including mean profiles of potential temperature, vapor mixing ratio, pressure, density, relative humidity and geometric height, from a given thermodynamic sounding. (Model Task 1)

- Model equations and dynamical framework.

  Theory: Details on formulations of terms and alternatives. (Chapter 3)

  Application: Assess convective instability of the sounding, using isobaric saturation adjustment. (Model Task 2)

- Solving the model equations, Part I.

  Theory: Finite difference approximations to one- and two-dimensional hyperbolic partial differential equations. Consistency and stability. CFL criterion. Upstream and leapfrog schemes (Chapters 4 and 5)

  Application: Set up code to implement model on two-dimensional, staggered grid in a laterally periodic domain. (Model Tasks 3 and 4)

- Solving the model equations, Part II.

  Theory: Dynamical frameworks. Anelastic approximation. (Chapter 6)

  Application: Model test problem: introduce buoyant thermal into model; compare results with theory and among students. Provoke linear computational instability. (Model Task 5)

- Nonlinear instability: causes and cures.

  Theory: Nonlinear computational instability and aliasing. Moisture. Microphysics. (Chapters 7 and 8)

  Application: Past final projects have included: simulation of a simple cloud, density currents, Rayleigh convection, sea-breeze and urban heat island circulations, atmospheric response to maintained heat sources, transport of passive tracers; flow into a channel or over a simple obstacle; assessment of sensitivity to artificial acoustic wave speed adjustment, and to different numerical schemes. (Model Task 6)

- Advanced topics.

  Theory: Adjoint models. (Chapters 16 and 17)

  Application: None.