Syllabus
CLIM 711 Introduction to Atmospheric Dynamics
Fall 2023
TR 9:00am – 10:15 am
Enterprise Hall, Room 77

Instructor: Prof. Cristiana Stan
Room 267, Research Hall
703-993-5391
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Course Credits: 3
Course Website: Blackboard
Office Hours: Thursday – 11:00 am-2:00 pm

Required Text:
Holton, James R. and Gregory J. Hakim, *An Introduction to Dynamic Meteorology*, Fifth Edition.

Assignments:
Periodic homework is assigned and is due at the start of the class indicated. No late homework will be accepted except under prior arrangement. Homework will be graded and returned. There will be one exam during the semester and a Final. Exams are designed to test basic concepts and are closed books and closed notes.

Grading:

Lectures, attendance and Class participation	10%	
Problem sets	45%	
Midterm Exam	20%	Thursday, October 12, 9 am – 10:15 am
Final	25%	Thursday, December 7, 7:30am – 10:15am

Course description
The basic conservation laws of mass, momentum, and energy for a rotating atmosphere are derived, and a scaling analysis of the equation of motion and the thermodynamic equation is performed. Balanced flows in the atmosphere (e.g., the geostrophic wind and its vertical shear, and the thermal wind relationship) are discussed. Circulation and vorticity are introduced and the quasi-geostrophic approximation is developed. Applications of the equations of motion include the atmospheric boundary layer, 2D and 3D Rossby waves, barotropic and baroclinic instability, the energy cycle, the ideal Hadley circulation, and the general circulation of the atmosphere. A knowledge of vector calculus, and familiarity with ordinary and partial differential equations is required.

Course Outline

1. Introduction

Newton's laws of motion, fundamental and apparent forces
Ideal gas law, hydrostatic law, material derivative, mass conservation, thermodynamic equation
The complete system of equations for a dry atmosphere

2. Balanced Flow

Trajectories and streamlines
Natural coordinates
Geostrophic flow
Inertial flow
Cyclostrophic flow
The gradient wind approximation

3. Fundamentals

Vorticity and circulation
Vorticity in natural coordinates
Vector vorticity equation
Circulation theorem
Potential vorticity
The impermeability theorem
Helicity

4. The exact primitive equations

Exact primitive equations in spherical coordinates

5. Primitive equations for shallow atmospheres

Primitive equations with the traditional approximation

6. The quasi-static primitive equations

Scale analysis
Geostrophic approximation and geostrophic wind

7. Transformation of the quasi-static primitive equation to a generalized vertical coordinate

The general vertical coordinate
Pressure coordinate; The thermal wind; Barotropic and baroclinic atmosphere
Log-pressure coordinate
Pseudo-height coordinate
Sigma coordinate
Isentropic coordinate
The ECMWF hybrid vertical coordinate

8. Divergent barotropic primitive equations (shallow water equations)

Horizontal momentum and continuity equations
Potential vorticity principle for the shallow water equations
Some numerical solutions

9. Nondivergent barotropic equations

From the divergent barotropic model to the nondivergent barotropic model
Emergence of coherent structures in two-dimensional turbulence
Waves and turbulence on a sphere

10. The shallow water equations on an f-plane

Linearization and nondimensionalization

Geostrophic adjustment: One-dimensional case

11. The shallow water equations on an equatorial β-plane

Linearization and nondimensionalization

Eigenvalues and eigenfunctions

12. The quasi-geostrophic equations

Vertical coordinate and thermal wind equations

Quasi-static primitive equations and quasi-geostrophic equations on an f-plane

Quasi-geostrophic potential vorticity equation

Two views of the omega equation

Q-vector form of the omega equation

Equivalence of the two forms of the omega equations

13. Barotropic Instability

The Rayleigh and Fjortoft necessary conditions for barotropic instability

14. Baroclinic Instability

Quasi-geostrophic theory

The Charney-Stern necessary condition for barotropic-baroclinic instability

The Eady problem

15. The Eckman layer

Reynolds averaging

Frictional mass transport

The laminar Ekman layer

Spin up and spin down

Basic Course Technology Requirements

Activities and assignments in this course will regularly use the Blackboard learning system, available at https://mymason.gmu.edu. Students are required to have regular, reliable access to a computer with an updated operating system (recommended: Windows 10 or Mac OSX 10.13 or higher) and a stable broadband Internet connection (cable modem, DSL, satellite broadband, etc., with a consistent 1.5 Mbps [megabits per second] download speed or higher. You can check your speed settings using the speed test on this website.)

Students can use Outlook to send a calendar invitation to the instructor for a meeting (though only the instructor can confirm a meeting).

Safe Return to Campus:

All students taking courses with a face-to-face component are required to follow the university's public health and safety precautions and procedures outlined on the university Safe Return to Campus webpage (https://www2.gmu.edu/safe-return-campus).

Students are required to follow Mason's current policy about facemask-wearing (https://www.gmu.edu/safe-return-campus/personal-and-public-health/face-coverings).

***University Requirements*:**
GMU is an Honor Code university; please see the Office for Academic Integrity for a full description of the code and the honor committee process. The principle of academic integrity is taken very seriously and violations are treated gravely. What does academic integrity mean in this course? Essentially this: when you are responsible for a task, you will perform that task. When you rely on someone else' s work in an aspect of the performance of that task, you will give full credit in the proper, accepted form. Another aspect of academic integrity is the free play of ideas. Vigorous discussion and debate are encouraged in this course, with the firm expectation that all aspects of the class will be conducted with civility and respect for differing ideas, perspectives, and traditions. When in doubt (of any kind) please ask for guidance and clarification.

If you have a documented learning disability or other condition that may affect academic performance you should: 1) make sure this documentation is on file with Office for Disability Services (SUB I, Rm. 4205; 993-2474;http://ods.gmu.edu) to determine the accommodations you need; and 2) at the beginning of semester talk with me to discuss your accommodation needs.

Students must use their Mason email account to receive important University information, including messages related to this class. See https://mail.gmu.edu for more information.

Course Materials and Student Privacy
All course materials posted to Blackboard or other course site are private to this class; by federal law, any materials that identify specific students (via their name, voice, or image) must not be shared with anyone not enrolled in this class.

- Videorecordings -- whether made by instructors or students -- of class meetings that include audio, visual, or textual information from other students are private and must not be shared outside the class
- Live video conference meetings (e.g. Collaborate or Zoom) that include audio, textual, or visual information from other students must be viewed privately and not shared with others in your household or recorded and shared outside the class

Other Resources for the General University Experience
- Student Support and Advocacy Center (SSAC)
- Counseling and Psychological Services
- The Office of Diversity, Inclusion, and Multicultural Education (ODIME)
- University Career Services
- University Writing Center