Syllabus
CLIM 711 Introduction to Atmospheric Dynamics
Fall 2024
TR 9:00am – 10:15 am
Innovation, Room 338

Instructor:	Prof. Cristiana Stan Room 267, Research Hall 703-993-5391 cstan@gmu.edu
Course Credits:	3
Course Prereqs:	BS or MS in mathematics or a physical science, or permission of instructor
Course Website:	Canvas
Office Hours:	Wednesday – 2:30pm-3:30pm Thursday – 1:00 pm-2:00 pm

Course Overview:
Covers basic conservation laws of mass, momentum, and energy and scaling analysis of equation of motion and thermodynamic equation. Discusses balanced flows in atmosphere, such as geostrophic wind and its vertical shear, and thermal wind relationship. Also explores circulation and vorticity; role of atmospheric boundary layer in mass, momentum, and energy transfer; synoptic scale motions; and role of gravity and Rossby waves in controlling general circulation of atmosphere.

Learning Outcomes:
This course is designed to enable students to:

1. Show an understanding of basic physical laws atmospheric dynamics
2. Students will recognize the mathematical framework and physical principles of atmospheric dynamics
3. Students will use the mathematical skills and physical principles to solving atmospheric dynamics problems

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 15, 9 am – 10:15 am
Final	25%	Thursday, December 12, 7:30am – 10:15am

The course is graded on the George Mason Graduate grading scheme. A grade of B- on the final exam is required as eligibility for Qualifying Exams.

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 Canvas learning system, available at https://mymason.gmu.edu and Zoom. 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).

Common Policies Addendum
Policies about Academic Standards, Accommodations for Students with Disabilities, FERPA, and Title IX affecting all GMU Students:

https://stearnscenter.gmu.edu/home/gmu-common-course-policies/

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 Canvas 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 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