CLIMATE/EARTH 401: Geophysical Fluid Dynamics (Fall 2023)

Instructor: Christiane Jablonowski (cjablono@umich.edu), 734-763-6238
office: Climate and Space Research Building (CSRB) 1541B
2455 Hayward St. (North Campus)
Location: 3433 EECS (classroom)
Time: TThu 1:30pm-3:05pm (90 minutes + 5 minute break)
10-minute extra time to make up lost time due to travel
term runs from 8/29-12/5/2023
Credits: 3 credit hours
Office Hour: Tuesdays after class (3:10-4pm), CSRB 1517
Wednesdays 4-5pm, CSRB 1517
No class on 10/12 & 10/19 (travel)
10/17 (Fall break) & 11/23 (Thanksgiving break)
Grader: TBD

Reference Textbook:

An Introduction to Dynamic Meteorology (5^{th} edition), chapters 1, 2, 3, 4, part of chapters 5, 6, 11
James R. Holton and Gregory J. Hakim, Elsevier Academic Press, 2012
pdfs of all chapters are freely available online via the UM library page

Course Outline and Learning Outcomes:

This course discusses the dynamics of geophysical flows with a focus on atmospheric motions. Students will be introduced to the forces that drive geophysical flows, the leading balances that arise from these forces, the importance of rotation (vorticity) and the temperature stratification, wave motions, quasi-geostrophic theory, and tropical dynamics processes.
The course includes in-class discussions, group exercises and homework problems that help develop the mathematical foundation and physical intuition necessary to understand the fundamental features of geophysical flows. Discussion of meteorological maps will be included. Students will learn how to use these maps to simplify the equations of motion and develop their physical understanding of the drivers of the phenomena. By the end of the course, students will be enabled to use mathematical tool as well as programming and visualization tools to describe the dominant motions of geophysical flows.

Schedule:

8/29	Introduction, overview of the course and logistics, motions on Earth, atmospheric layers, difference between weather and climate, physical units and scales, conservation laws, terminology and definitions
8/31	Some basics: composition of the atmosphere, ideal gas law, hydrostatic equation, mass, pressure, geopotential, hypsometric (thickness) equation, layer-mean temperature
9/5	Introduction to NetCDF data and plotting techniques, mathematical tools (vectors, operators), divergence and vorticity, shearing and stretching deformations, 2D and 3D gradients, spherical coordinates, material derivative, advection, numerical derivatives, unweighted and weighted averages, vertical interpolations
9/7	Forces: Pressure gradient force, viscous force, gravitational force, centrifugal force, definition of gravity, Coriolis force (HW1 due)
9/12	Review of the momentum equations, scale analysis, geostrophic & hydrostatic balance, ageostrophic wind
9/14	Continuity equation, thermodynamic equation, scale analysis, vertical coordinate transformations, equations of motion with other vertical coordinates (e.g. the pressure coordinate), conservation principles (HW2 due)
9/19	Geostrophic balance in pressure coordinates, thermal wind, vertical motions, surface pressure tendency
9/21	Thermodynamic profiles, Brunt-Väisälä frequency, static stability, potential temperature, dry adiabatic lapse rate, definition of the tropopause (HW3 due)
9/26	Balanced flows in natural coordinates
9/28	Balanced flows in natural coordinates, stream functions and trajectories, development of low pressure systems (HW4 due)
10/3	Excursion: inclusion of moisture in the equations of motion, impact of moisture
10/5	Review for exam 1 (HW 5 due, data analysis project out)
10/10	Exam 1 (in class 1:30-3:20pm)
10/12	no class (travel), work on data analysis project
10/17	Fall break (no class)
10/19	no class (travel), work on data analysis project
10/24	Discussion of exam 1
10/26	Vorticity, vorticity equation (data analysis project due)
10/31	Barotropic/baroclinic atmospheres, barotropic vorticity equation, potential vorticity
11/2	Conservation of potential vorticity, circulation (HW6 due)
11/7	Introduction to waves, linear perturbation theory
11/9	Shallow water equation set, 1D shallow water waves (HW 7 due)
11/14	2D shallow water waves, 2D midlatitudinal (Rossby) waves, structure of extratropical motions
11/16	Introduction to quasi-geostrophic (QG) theory, QG vorticity equation, waves in the QG system
11/21	QG geopotential tendency and potential vorticity equations (HW 8 due)
11/23	No class, Thanksgiving
11/28	QG omega equation, applications of the QG theory: extratropical cyclones, midlatitudinal dynamics
11/30	Tropical dynamics, hurricanes
12/5	Review for exam 2 (HW 9 due on 12/6 8pm)

12/12 Tuesday Exam 2, in class 1:30-3:30pm, (regular final exam slot for this class)

Expectations and grading policy:

Students will be evaluated based on weekly/biweekly homework assignments (9 total), a data analysis project, and two exams. Unless otherwise specified, homework assignments will be due one week from the day they are assigned. Late assignments will not be accepted without prior approval from an instructor.

Your final grade will be determined by your performance on the two midterm exams, the homework sets, and the data analysis project. The grade breakdown is:

Homework sets (9)	40 %
Data analysis project	10 %
First exam	25 %
Second exam	25 %

There are 9 graded homework assignments, each assignment has equal weight (despite a varying number of points for each homework assignment) and contributes 4.44% to your final grade.

You are encouraged to form study groups to work on homework problems and to study in other ways. You are allowed to consult with other students during the conceptualization of a problem. However, all written work, whether in scrap or final form, is to be generated by you alone.

The College of Engineering Honor Code is enforced:
https://bulletin.engin.umich.edu/rules/

Lecture Recordings and Virtual Participation:

The lecture recordings are available via the Canvas page and will be posted after each lecture. An online Zoom option will not be offered. In-person participation is preferred which provides a more interactive learning and discussion environment.