Geophysical Fluid Dynamics – MATH-GA.3001-001

Fall 2025

Course Description

Geophysical Fluid Dynamics (GFD) applies fluid dynamics to stratified fluids in a rotating reference frame. Rotation and stratification shape the atmosphere and ocean, giving rise to the jet stream, hurricanes, the Gulf Stream, and even the bands on Jupiter.

In this course we will study the equations describing these motions, but just as importantly, we will build the physical intuition that makes GFD one of the most fascinating areas of fluid dynamics. Among these ideas are the shallow water model, which captures the essence of large-scale motion; potential vorticity, a conserved quantity that guides our intuition; and baroclinic instability, a fluid instability that is uniquely geophysical and drives ocean eddies and atmospheric storms. See the schedule on the second page for more details.

Instructor

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Logistics

- **Class time:** Tuesday and Thursday, 2:00–3:15 PM, Warren Weaver Hall 517
- **Office hours:** Tuesday and Thursday, 3:15–4:15 PM, Warren Weaver Hall 909

Assessment

Completion of four problem sets and a take-home final exam.

References

- *Atmospheric and Oceanic Fluid Dynamics*, G. Vallis (Cambridge, any edition)
- *Lectures on Geophysical Fluid Dynamics*, R. Salmon (Oxford, 1998)
- *Waves in the Ocean and Atmosphere*, J. Pedlosky (Springer, 2003)
- *Geophysical Fluid Dynamics*, J. Pedlosky (Springer, 1987)

Lecture Schedule

Week	Dates	Topics / Notes
1	9/2, 9/4	Introduction to GFD, continuum hypothesis, Lagrangian/Eulerian perspectives, material derivatives, Coriolis force, momentum equation, mass conservation, Taylor-Proudman theorem
2	9/9, 9/11	Shallow-water model, potential vorticity, wave kinematics, shallow water gravity waves and inertia-gravity waves
3	9/16, 9/18	Poincaré and Kelvin modes, Rossby adjustment problem, shallow water QG dynamics
4	9/23, 9/25	QG energy conservation, beta-effect, shallow-water Rossby waves
5	9/30, 10/2	Rossby wave with background flow, stationary waves, radiation condition, momentum flux, Kelvin-Helmholtz instability
6	10/7, 10/9	Barotropic instability, intuition for Rayleigh's and Fjørtoft's criteria
7	10/16	Two-layer shallow water model
8	10/21, 10/23	Two-layer QG dynamics, Philips's model of baroclinic instability, Charney-Stern-Pedlosky criterion, pseudomomentum conservation
9	10/28, 10/30	2D turbulence, Beta-plane turbulence, continuous stratification, Boussinesq model, internal waves
10	11/4, 11/6	Reflection of internal waves at solid boundary, propagation in non-uniform medium (WKB), topographic generation of internal waves, Kelvin's circulation theorem
11	11/11, 11/13	Ertel PV, 3D Boussinesq model with rotation, vertical modes, 3D QG dynamics in Boussinesq model, surface QG, Eady's model
12	11/18, 11/20	Sverdrup balance, boundary layer theory, wind-driven gyre, Ekman layer
13	11/25	Skipped
14	12/2	Equatorial waves (Yanai, Poincaré, Rossby, Kelvin modes)