270.653: Fluid Dynamics of the Earth and Planets II
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This course concentrates on aspects of planetary-scale atmospheric and oceanic circulation, plus rotating-stratified waves. We emphasize physical understanding of the underlying fluid dynamics throughout.

The course is a sequel to 270.425 Fluid Dynamics of the Earth and Planets I. It also complements 270.626 Ocean General Circulation by elucidating and generalizing theories of rotating-stratified flow.

Synopsis

1. *Shallow-water dynamics:* Inertia-gravity waves. Geostrophic adjustment. Two-layer system and normal modes. Energetics.
2. *Potential vorticity and balance:* Rossby wave propagation (horizontal). Primitive Equations. Rossby wave propagation (vertical).
3. *Large-scale Ocean Circulation:* ~~Theory of the pycnocline and gyre circulation. Meridional overturning circulation and deep-western boundary currents. Buoyancy-driven circulations: Stommel-Arons Model, Sandstrom's theorem. Box models of meridional overturning circulation.~~ Eddies and instabilities: Hierarchy of rotating-stratified instabilities (gravitational, inertial, symmetric, baroclinic). Parametrization of baroclinic eddies. Baroclinic eddy-equilibrated mean flow.
4. *Large-scale Atmosphere Circulation*: Baroclinic instability. Zonal-mean circulation, Eliassen-Palm theory and the transformed-Eulerian mean equations.

Assessment will be by homeworks (probably one on each section of the class) and a final oral exam.

We will meet twice each week online (synchronously) for 75 minute classes. Schedule: Tuesdays & Thursdays, 9:00–10:15am. Materials will be posted to Blackboard. There are no formal, regular office hours but both instructors are available for zoom meetings if required (send email to request a meeting).

Learning Goals

1. State the shallow-water equations for a single layer of fluid, and discuss the physical regimes where they apply.

2. Discuss the physics of inertial oscillations, inertia-gravity waves, and geostrophic adjustment.

3. Define and describe potential vorticity, including its form in different models, and explain why it is useful.

4. Explain the physical mechanisms of Rossby waves, outline the derivation of their dispersion relation, and discuss their horizontal and vertical propagation.

5. ~~Describe the general circulation theories for the pycnocline, subtropical gyres, and meridional overturning circulation.~~ Describe the criteria for instability and the growth rates of: gravitational, inertial, symmetric, and baroclinic instability.

6. Explain different approaches to parameterize the effects of unresolved processes in ocean general circulation models.

7. Describe the mechanisms of barotropic and baroclinic instability, and illustrate with examples from the atmosphere or ocean.

8. Describe the zonal-mean circulation in the atmosphere, and compare theories for the latitudinal extent of the Hadley Cell.

Textbooks

- *Basic principles:*
  - Cushman-Roisin, B., and J.-M. Beckers, 2011: Introduction to Geophysical Fluid Dynamics, 2nd edition, Academic Press.
  - Marshall, J., and Plumb, R. A., 2008, Atmosphere, Ocean, and Climate Dynamics: An Introductory Text, Elsevier.
- *Recommended, and at the level of the class (although we won't cover all this material):*
  - Vallis, G. K., 2006. Atmospheric and Oceanic Fluid Dynamics. Cambridge University Press, 745 pp.
  - Klinger, B. A., and Haine, T. W. N., 2019, Ocean Circulation in Three Dimensions, Cambridge University Press, 494 pp.
- *Other useful texts:*
  - McWilliams, J. C., 2006, Fundamentals of Geophysical Fluid Dynamics, Cambridge University Press, 249 pp.
  - Pedlosky, J., 1996, Ocean Circulation Theory, Springer-Verlag.
  - Salmon, R., 1998, Lectures on Geophysical Fluid Dynamics, Oxford University Press.
  - Pedlosky, J., 1987, Geophysical Fluid Dynamics, Springer-Verlag.

Academic Integrity

The strength of the university depends on academic and personal integrity. In this course, you must be honest and truthful. Ethical violations include cheating on exams, plagiarism, reuse of assignments, improper use of the Internet and electronic devices, unauthorized collaboration, alteration of graded assignments, forgery and falsification, lying, facilitating academic dishonesty, and unfair competition.

In addition, the specific ethics guidelines for this course are:

- Work collaboratively on homework problems, including sharing codes. But work on your own on write ups and clearly identify whom you worked with and how.

Report any violations you witness to the instructor. Please see the website https://studentaffairs.jhu.edu/student-life/student-conduct/resources-conduct-ethics/ for more information.

Disability Services

Any student with a disability who may need accommodations in this class must obtain an accommodation letter from Student Disability Services, 385 Garland, (410) 516-4720, studentdisabilityservices@jhu.edu

Anxiety, Stress, and Mental Health

If you are struggling with anxiety, stress, depression or other mental health related concerns, please consider accessing resources such as: the Counseling Center, Mental Telehealth, and/or Student Wellness. If you are concerned about a friend, please encourage that person to seek out these services too.