CEE/EESS 363F
Oceanic Fluid Dynamics
Spring Quarter 2009
Version 4/1/09

CLASS HOURS & LOCATION:
Monday, Wednesday, and Friday 2:15pm – 3:05pm.
Lectures Y2E2 Room 155, Labs Y2E2 B51

INSTRUCTOR: Leif Thomas
leift@stanford.edu
Y2E2 Room 181
Office hours: TBA.

TEACHING ASSISTANT: Matt Long
mclong@stanford.edu
Green Earth Sciences Room 239
Office hours: TBA

TEXT:
Primary text: Introduction to Geophysical Fluid Dynamics, Physical and Numerical Aspects, by B. Cushman-Roisin and J-M Beckers. Academic Press.
http://engineering.dartmouth.edu/~cushman/books/GFD.html
Recommended text: Atmospheric and Oceanic Fluid Dynamics, Fundamentals and Large-scale Circulation, by G. Vallis, Cambridge University Press, 2006.
Geophysical Fluid Dynamics, 2nd Edition, by J. Pedlosky, Springer 1986.

GRADING:
Four problem sets: 80%
Class participation: 20%
Students will be required to participate in problem solving sessions in which they derive and discuss solutions to the problem sets on the board. Students will also be required to participate in laboratory demonstrations used to illustrate key concepts in oceanic fluid dynamics and write short descriptions of what they observe.

COURSE DESCRIPTION:
The fundamental dynamics of rotating stratified fluids with application to oceanic flows. Topics include inertia-gravity waves, geostrophic and cyclogeostrophic balance, vorticity and potential vorticity dynamics, quasi-geostrophic motions, planetary and topographic Rossby waves, inertial, symmetric, barotropic, and baroclinic instability, Ekman layers, and the frictional spin-down of geostrophic flows. Prerequisite: CEE 262A or a graduate class in fluid mechanics. Recommended math background: vector calculus, ordinary differential equations, and some knowledge of partial differential equations.

LECTURES & LABS:

Lecture 1: Importance of rotation and stratification for oceanic flows, scales of motion, and description of phenomena. Introductory lab demo: constraints imposed by rotation and stratification on fluid motion. *CR 1*.
Lecture 2: Review of the equations of fluid motion, the Boussinesq approximation, and the shallow water equations. *CR 3.1-3.7, 7.3*.
Lecture 3: Equations of motion in a rotating coordinate frame, the physics behind the Coriolis force, the geopotential, and inertial motions. *CR 2.1-2.5*.
Lecture 4: Effects of stratification, static stability, and inertia-gravity waves. *CR 11.1-11.2, 13.1-13.3.*
Lab 1: Solid body rotation: geopotential surfaces, inertial oscillations, and the Foucault pendulum.
Lecture 5: Balanced motions, geostrophic and cyclogeostrophic balance, geostrophic streamfunction, inertial instability. *CR 7.1,18.2*
Lecture 6: Vorticity dynamics: vortex squashing/stretching/tilting, baroclinic and frictional torques, the thermal wind balance, and the Taylor-Proudman theorem. *CR 7.4, 15.1, V 4.1-4.3, P 2.1-2.4.*
Lecture 7: Shallow water form of the potential vorticity, conservation and invertibility, and geostrophic adjustment: *CR 7.4, V 3.8*
Lecture 8: Kelvin waves, coastal and equatorial. *CR 9.2*
Lab 2: Cylinder collapse experiment: thermal wind balance, geostrophic adjustment, vortex stretching/squashing.
Lecture 9: Potential vorticity in layered models and for continuous stratification, Ertel potential vorticity and hydrodynamic stability. *CR 12.1-12.4, 17.2, V 4.5, P 2.5*
Lecture 10: The shallow water quasi-geostrophic equations, barotropic planetary Rossby waves. *CR 9.4, V 5.3 , 5.7.*
Lecture 11: Topographic Rossby waves, Orr-Sommerfeld/Rayleigh's equation, vorticity waves, and barotropic instability. *CR 9.5, 10.1-10.4*
Lecture 12: Quasi-geostrophic equations for layered and continuously stratified systems, baroclinic planetary Rossby waves. *CR 16.1-16.6, V 5.3-5.4.*
Lab 3: Taylor columns, vortex propagation on a topographic beta plane.
Lecture 13: The available potential energy, baroclinic instability in a two layer model. *CR 16.4, 17.3-17.6, V 6.7.*
Lecture 14: Baroclinic instability in a continuously stratified fluid, edge waves and the Eady problem *V 6.5, 6.7*
Lecture 15: Ekman flows in the surface and bottom boundary layers, the Ekman spiral, Ekman transport/pumping/suction, the turbulent Ekman layer. *CR 8.1-8.7, V 2.12*
Lecture 16: Frictional spin-down of geostrophic flows. *V 2.12.6, P 4.7*
Lab 4: Baroclinic instability in the rotating annulus experiment.
Lecture 17: Vertical modes and lee waves. *CR 13.4-13.5*
Lecture 18: Inertia-gravity waves in non-homogeneous media, ray tracing.
Lab 5: Ekman layers and the spin-down of a vortex.

Recommended readings are highlight in italics, where the abbreviations stand for: *CR*- Cushman-Rosin and J-M Beckers; *V*- Vallis; and *P*- Pedlosky