



MATH 5xx: Environmental and Geophysical Fluid Dynamics Spring 2007

Class Hours: MWF 11:00-12:00, WEIR 133

Prerequisites: MATH 236 (Introduction to PDEs), MATH 231 (Calculus 3)

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Literature:

- [1] Dynamics of Atmospheric Motion, *J.A., Dutton, Dover Publications* (1976)
- [2] Atmosphere-Ocean Dynamics, *A.E., Gill, Academic Press* (1982)
- [3] Lectures on Geophysical Fluid Dynamics, *R.Salmon, Oxford University Press* (2001)
- [4] Small Scale Processes in Geophysical Fluid Dynamics, *L. Kantha, C.A., Clayson, Academic Press* (2004)

1. Description of the subject

Earth's atmosphere and oceans exhibit complex patterns of fluid motion over a vast range of space and time scales. Moving fluids are a part of the natural world, and their dynamics impact the ocean and atmosphere as well as many other problems of science and engineering. Fluid processes are complex (the equations of motion are three-dimensional, unsteady and nonlinear) and the theory is incomplete. Many natural processes occur over too large a scale in time and space (ten orders of magnitude in length-scale variations for the flows in the ocean) so that even the most advanced computer models cannot adequately describe real systems.

Environmental and Geophysical Fluid Dynamics is primarily concerned with fluid flow in rivers, lakes, oceans and the atmosphere. Such flows dominate our physical existence. Geophysical Fluid Dynamics (GFD) is traditionally the study of naturally occurring large scale fluid motions in the oceans and in the atmosphere which are affected by the Earth's rotation, but also includes extraterrestrial atmospheres and the interior of the gas giants such as Jupiter. Examples of large scale motions are the Gulf Stream in the North Atlantic Ocean and atmospheric blocking events, one of which was responsible for the great heat wave in Europe in 2003. Over the past 30 years attention has been increasingly focussed on the impact of large scale fluid flows on the environment, highlighted by fundamental issues such as global warming and long-term climate change.

Smaller scale motions, such as turbulence and mixing caused by internal waves, and surface water waves have a direct impact on bio-geochemical processes in oceans and lakes and hence on human activity. Due to their ubiquitous nature, these motions are also of fundamental importance to the large scale circulation in both the oceans and atmosphere.

2. Aim of the Programme

This course will examine fluid motions in the atmosphere and ocean for which the earth's rotation cannot be ignored. It covers the essential GFD required for atmospheric science and oceanography courses. Math 5xx provides students with mathematically rigorous, concise coverage of basic theory and applications to both oceans and atmospheres.

The goal of the course is to better understand of the nonlinear wave processes and to understand what effects the waves have on their environment.

3. About the course

This course is a concise and accessible introduction to GFD for intermediate to advanced students interested in the physics, chemistry, and/or biology of Earth's fluid environment. The course is developed from the author's several years of research and teaching first-year graduate courses in Fluid Mechanics at the Novosibirsk State University (Russia), University of Port Elizabeth (South Africa) and McMaster University (Canada). Students are expected to be familiar with basic concepts of physics and mathematics at the level of general dynamics (mechanics) and partial differential equations.

The topics of lectures are outlined below.

1. Importance of GFD. Geophysical examples. Scales of motion. Importance of rotation and stratification.
2. Equations of motion. Internal waves. Dispersion relation. Orthogonality of Group and Phase velocities
3. Flow over topography.
4. Nonlinear wave interactions.
5. Geophysical Flow. Internal wind. Taylor-Proudman theorem. The Rossby and Ekman numbers. The f – plane and β – plane. Ekman layer at free and rigid surfaces.
6. High and low frequency regims in shallow water equations. Vorticity equation. Kelvin waves. Rossby waves.
7. Barotropic instability. Perturbation vorticity equation. Baroclinic instability.
8. Review of Geostrophic Instabilities and General Circulation Model.

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