MPO 752: Vortex Dynamics

Spring 2017

Dr. David S. Nolan; contact: dnolan@rsmas.miami.edu, 305-421-4930

Class times: Monday, Wednesday, 4:30-6:00PM, MSC329;

also some classes on Fridays, times to be determined.

Summary:
This course will cover fundamental to advanced topics in vortex dynamics. Beginning with a review of fluid dynamics and vorticity in two dimensions, we will study a variety of exact and approximate solutions that describe two-dimensional vortex behavior. This process with then be repeated for three-dimensional vortex dynamics in unstratified flow, and then for three-dimensional vortex dynamics in stratified flow, with applications to vortices in the atmosphere and ocean.

Outline:

I. Two-Dimensional Flow

A. Equations of motion
B. Circulation and vorticity
C. Vorticity and streamfunction equations
D. Stationary solutions
E. Asymmetric vortex dynamics
F. Asymmetric solutions

II. Three-Dimensional Flow

A. Equations of motion in three dimensions
B. Vorticity inversion and Green's functions
C. Vortex filaments and rings
D. Stretching, folding, and turbulence

III. Three-dimensional, stratified flow

A. Equations of motion
B. Potential vorticity and inversion
C. Asymmetric vortex dynamics in stratified flow
D. Balanced vortex dynamics
E. Boundary layers

IV. Term Projects

The term projects will require each student to use one or two previously developed numerical models of fluid motion and vortex dynamics that may include (but are not limited to): a vortex-method model of two-dimensional flow, a vortex-method model of three-dimensional flow, a

grid-based model of two-dimensional flow, a nonlinear model of axisymmetric flow, a linear model of asymmetric vortex dynamics in the shallow water equations, and a linear model of asymmetric vortex dynamics in stratified flow. Each student will propose a simple phenomenon and/or question to investigate, and then perform a small set of calculations or numerical simulations to address them. The work will be presented in two short presentations and a short term paper.

Assignments:

There will be occasional homeworks (30%), an exam (30%), and a research project with a short presentation (10%), a long presentation (15%), and a short paper (15%).

Resources:

The class will not follow a single textbook. However, we will use readings and material from a variety of textbooks and monographs, some of which will be:

Batchelor, G. K., 1967: *An Introduction to Fluid Mechanics*.

Chorin, A. J., 1994: *Vorticity and Turbulence*.

Chorin, A. J., and J. E. Marsden, 1993: *A Mathematical Introduction to Fluid Mechanics*.

Drazin, P. G., 1982/2003. *Hydrodynamic Stability*.

Gustafson, K. E., and J. A. Sethian, 1991: *Vortex Methods and Vortex Motion*.

Lamb, H., 1932/1993. *Hydrodynamics*.

Kundu, P. K., and I. M. Cohen, 2002: Fluid Mechanics.
Also: 2012 edition, with D. M. Dowling, available only online through the library catalog.

Saffman, P. G., 1992: *Vortex Dynamics*.

Vallis, G. K., 2006: *Atmospheric and Oceanic Fluid Dynamics*.

Research project papers from previous years:

Moon, Y., 2010: *The formation of a concentric vorticity ring from the interaction of vortex patches.*

Yamaguchi, Y., 2010: *Normal mode analysis for a baroclinic tropical cyclone-like vortex.*

Zhu, Z., 2010: *Numerical tests on vortex polygons.*

Bhatia, K., 2011: *Testing the ability of 2-dimensional vortex methods to reproduce simulations of nearly inviscid vortex dynamics.*

Komaromi, W., 2011: *The combined effects of beta-shear and environmental shear on a dry tropical cyclone in a numerical model.*

McGauley, M., 2011: *Vorticity thresholds in developing storms.*

Sellwood, K., 2011: *The evolution of perturbations in a balanced vortex.*

Wu, T., 2011: *Examining vortex Rossby wave (VRW) dispersion relations with numerical experiments.*

Blanco, J., 2013: *Simulations of ITCZ breakdown with 2D vortex methods.*

Finocchio, P., 2013: *Simulated interactions between symmetric tropical cyclone-like vortices.*

Onderlinde, M., 2013: *Simulating the effects of low-level stability on tornadogenesis and tornado structure.*

Rudko, M., 2013: *Dynamics of the ocean rings on the beta plane in quasi-geostrophic two-layer model.*