

## **Interdisciplinary Research and Training at the Geophysical Fluid Dynamics Program**

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### **LONG-TERM GOALS**

The long-term goals are to train new scientists to conduct research, and to enhance the abilities of experienced research workers in Geophysical Fluid Dynamics (GFD). This field is fundamental to the field of numerical forecasting of ocean, atmosphere and environment.

### **OBJECTIVES**

To help graduate students formulate and tackle innovative research problems in GFD. To promote an exchange of knowledge and ideas between investigators in the different scientific disciplines that deal with the dynamics of stratified fluids, rotating fluids, nonlinear waves, bio-fluid dynamic interactions, etc. To formulate tractable, important problems which are presently at the fringe of our understanding in the field of Geophysical Fluid Dynamics. To serve as a clearing-house for the mathematical, experimental and computational techniques which serve astrophysics, climate science, geodynamics, meteorology and oceanography.

### **APPROACH**

We conduct a summer study school of ten weeks duration each summer. The participants are graduate student Fellows, visiting graduate students and visiting scientists. The first two weeks consist of ten principal lectures in the summer's topic conducted by an expert in that area. Lectures by associated participants follow at a rate of roughly one or two per day for the remaining weeks except for the last two weeks, when student Fellows are given time to complete and then present their results. About 10 graduate students are admitted as Fellows, selected from a pool of applicants from many disciplines who are in their second to fourth year of graduate school. Fellows receive a stipend for the full ten

weeks. A Fellow conducts a research project under the guidance of the staff, provides a written project report, and orally present results in the tenth week. The Fellows also prepare note of the principal lectures. Several other graduate students visit for shorter periods to listen to lectures and interact with the staff. The faculty and staff (comprised of the faculty and the visiting scientists) are continually renewed throughout the summer, although there is a core group of faculty and several visitors (e.g. principal lectures) who remain for the entire summer. Most of these participants receive partial travel support from the program, but some participate for free. The lecture notes and the written report of the Fellows' projects are contained in a volume that is available on the GFD website and distributed in print form to certain organizations/individuals. Finally, a public lecture is presented each year on a topic of interest to the general public.

The program is governed and run by a faculty comprised of many leaders in their fields. The faculty are:

Neil Balmforth	Department of Mathematics, University of British Columbia
Oliver Buhler	Courant Institute, NYU
Colm-Cille Caufield	DAMTP, University of Cambridge
Claudia Cenedese	Woods Hole Oceanographic Institution
Eric Chassignet	RSMAS/MPO, University of Miami
Steve Childress	Courant Institute, NYU
Charles Doering	Department of Mathematics, University of Michigan
Glenn Flierl	Department of Earth, Atmospheric and Planetary Sciences, MIT
Pascale Garaud	Department of Applied Mathematics and Statistics, University of California, Santa Cruz
Karl Helfrich	Woods Hole Oceanographic Institution
Louis Howard	MIT, Florida State University, and Duke University
Joseph B. Keller	Stanford University
Norm Lebovitz	Department of Mathematics, University of Chicago
Stephan Lewellyn-Smith	Department of Mechanical and Aerospace Engineering & Scripps Institution of Oceanography, UCSD
Willem Malkus	Department of Mathematics, MIT
Philip Morrison	Physics Department, University of Texas at Austin
Micheal Proctor	DAMTP, Cambridge University
Antonello Provenzale	Istituto di Scienze dell'Atmosfera e del Clima, CNR Italy
Ed Spiegel	Astronomy Department, Columbia University
Jean-Luc Thiffeault	Department of Mathematics, University of Wisconsin
George Veronis	Department of Geology and Geophysics, Yale University
John Wettlaufer	Departments of Geology and Geophysics & Physics, Yale University
Jack Whitehead	Woods Hole Oceanographic Institution
William Young	Scripps Institution of Oceanography, UCSD

## **WORK COMPLETED**

This year's program ran from June 20 to August 26, 2011. The subject of 2011 principal lectures was "Shear Turbulence: Onset and Structure." Fabian Waleffe (U. Wisconsin) and Richard Kerswell (Bristol University) shared the principal lecture duties. There were also 38 seminars given by both

long- and short-term visitors to the program with topics ranging from the summer theme to topics across fluid dynamics and oceanography.

The names of the 2011 Fellows, university affiliations, and titles of their projects were:

Matthew Chantry, University of Bristol, “Traversing the edge: how turbulence decays.

Andrew Crosby, University of Cambridge, “Chaotic interaction of vortex patches with boundaries.”

Martin Hoecker-Martinez, Oregon State University, “Constraints on low order models: the cost of simplicity.”

Keiji Kimura, Kyoto University, “A one-fluid MHD model with electron inertia.”

Chao Ma, University of Colorado at Boulder, “On Brownian motion in a fluid with a plane boundary.”

Giulio Mariotti, Boston University, “A low dimensional model for shear turbulence in Plane Poiseuille flow: an example to understand the edge.

Adele Morrison, Australian National University, “Upstream basin circulation of rotating hydraulically controlled flows.”

John Platt, Harvard University, “Localized solutions in plane Couette flow: continuation methods.”

Samuel Potter, Princeton University, “Islands in locally forced basin circulations.”

Lindsey Ritchie, University of Strathclyde, “Ascending the ridge: maximizing the heat flux in steady porous medium convection.”

Zhan Wang, University of Wisconsin, Madison, “Two-layer viscous fluid in an inclined closed tube: Kelvin-Helmholtz instability.”

Finally, the GFD public lecture was held on August 4, 2011 and was attended by over 100 people. The lecturer was Professor Lakshminarayanan Mahadevan, Harvard University who spoke on “On Growth and Form: Geometry, Physics and Biology.”

## **RESULTS**

The Principal Lectures and Fellows' reports are the most tangible results. The 2010 program material is now available as a technical report on the GFD website (<http://www.who.edu/page.do?pid=68676>) maintained at the Woods Hole Oceanographic Institution. The results of the 2011 program will be posted to the GFD website early in 2012. Further, most of the 52 years of GFD Proceeding volumes have been scanned into the Open Access Server of the Woods Hole Scientific Community (<https://darchive.mblwhoilibrary.org/handle/1912/11>). A large number of published journal papers

typically result from each summer's program. This includes Fellows' reports that frequently become journal articles as well as papers that arise from interactions between the GFD Faculty and visitors.

## **IMPACT/APPLICATIONS**

The GFD program advances discovery and understanding, while promoting teaching and training by involving graduate students in research. The research performed by the student Fellows at GFD sometimes provides the backbone of their doctoral theses. On other occasions, it introduces the Fellows to new problems in different areas, allowing them to broaden their research interests and acquire new tools from other disciplines to use in their own research. Above all, for many of the Fellows it provides the basic knowledge of how to conduct a research project and how to develop the work into a presentable, coherent form and into publishable scholarly articles. The opening lectures at GFD are meant to provide an introduction to a new field to both the students and experts from other disciplines, and seminars throughout the summer often have a pedagogical flavor.

By virtue of its very discursive and interactive style, GFD naturally promotes the dissemination of scientific results amongst researchers from very different backgrounds; techniques from different disciplines are readily transferred across disciplinary borders, and parallels between problems in very different fields can be easily appreciated. GFD also initiates discussion between leading experts as well as very inexperienced, beginning researchers, exposing all to current scientific ideas and technological understanding. Through the setting at the Woods Hole Oceanographic Institution, GFD brings university professors and students from a more academic background to this center of modern oceanography.

The staff pays close attention to each fellow and works to make each fellow achieve a good project in conjunction with a suitable advisor. The WHOI Academic Programs Office also has the Fellows evaluate the program, and the vast majority of comments are highly complementary.

We estimate that typically 20-50% of the student projects become included in their thesis or postdoctoral work and/or result in publications. The program does not follow the Fellows' research after the summer is finished. However, the interaction between advisor and Fellow usually carries on beyond the length of the summer school and brings tangible results like journal publications or reference letters that the advisor can provide for the Fellow.

## **REFERENCES**

Various features of the program are contained on GFD website listed above. These include a list of past Fellows, the titles of the lectures, a list of participating scientists, a yearly newsletter, and recent past volumes (containing lecture notes and the fellows' project reports).

## **PUBLICATIONS**

Lecture notes and fellows reports are maintained on the GFD website.