

# **Interdisciplinary Research Programs in Geophysical Fluid Dynamics**

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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.

## **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 and rotating fluids. 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 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 week, when student fellows present their results. Approximately ten graduate students are admitted as Fellows. Each Fellow receives a stipend for the full ten weeks, conducts a research project under the guidance of the staff and provides a written project report. The fellows also write up the principal lectures. Several other graduate students visit for shorter periods to listen to lectures and interact with the staff. The staff (i.e. all of the visiting scientists) is continually renewed by inviting new participants from the various disciplines with an interest in rotating, stratified fluid flows. Most of these participants receive partial support from the program. Continuity is provided by a small group of participants who attend regularly (once every two years or more frequently). Little direct support is provided to this latter group. The lecture notes and the written report of the fellows' projects are contained in a volume that will be distributed in print form and put on the Web.

# Report Documentation Page

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## WORK COMPLETED

The effects of bounds on turbulent transport was introduced in a series of five lectures by F. H. Busse. Although the technique has classical roots it owes its modern origins to studies of convection decades ago at the GFD program. These solutions share many properties, such as temperature profiles or shear flow profiles, with actually realized turbulent velocity fields, as illustrated by the Howard-Busse approach to this problem. In recent years the Doering-Constantin approach to the bounding problem has been developed and the equivalence of the two approaches has been demonstrated. These and several other advances have derived improved bounds on turbulent transports in recent years through the use of additional constraints and through the introduction of computational methods. These were reported in lectures by P Constantine, R. Kerswell, L Howard, C. Caulfield and C. Doering. This more theoretical topic was complemented with a mini symposium on rotating convection in early July, which included presentations of experimental, ocean atmospheric and planetary observations. They share common features with the variational problems such as sequences of successive bifurcations and multiplicities of states.

During the rest of the program, participants and visitors who have studied turbulence, convection, and instability in numerous geophysical situations with application to the ocean, the earth's atmosphere and planetary circulation made numerous contributions with approximately 40 additional lectures. The ten fellows selected this year were selected from a pool of applicants who are graduate students from many disciplines in their second to fourth year. There was high international interest in the topic covered this summer. The fellows, their affiliation, and their report titles this year were:

Jennifer Siggers, University of Cambridge, UK "Bounds for Horizontal Convection"

Radostin Simitev, University of Bayreuth, GERMANY "Inertia Wave Convection in Rotating Spherical Fluid Shells"

Lu Lu, University of Michigan "Upper Bounds for Convection in an Internally Heated Fluid Layer"

Ulrike Riemenschneider, University of Southampton, UK "Ball Release Experiment in a Centrifuge"

Huiqun Wang, California Institute of Technology "Rearrangement of Annular Rings of High Vorticity"

Francois Petrelis, Ecole Normale Supérieure de Paris, FRANCE "Bounds in MHD Turbulence I Tearing Models"

Alexandros Alexakis, University of Chicago "Bounds in MHD Turbulence II Magnetic Couette Flow and Hartmann Flow"

Tomoki Tozuka, University of Tokyo, JAPAN "On the Cyclic and Oscillatory Convections in a Simplified Box Model With Entrainment"

Evstati Evstatiev, The University of Texas, Austin "Boundary Layer Theory for the Fixed Heat Flux Problem"

Stephen Plasting, University of Bristol, UK "Infinite Prandtl Number Convection: Bound to Disprove"

A number of features, such as a list of past fellows, the titles of the lectures, a list of participating scientists, and recent past volumes, are listed on the web at <http://www.who.edu/gfd>. Eric Chassignet, Glenn Flierl and Jean-Luc Thiffeault must be thanked for their important contributions to overseeing the computer facilities.

## **RESULTS**

The principal lectures and fellows' reports are the tangible results. They are available as a technical report and on the web. A list of summer talks is also on the web.

## **IMPACT/APPLICATIONS**

The experiences of the fellows and the staff are difficult to quantify. Many express their enthusiasm at the end of each summer. We conducted a survey last summer for the past 20 years of fellows as part of the celebration of the 40<sup>th</sup> year of the program. About 80% of the remarks were highly complimentary. Some fellows had serious suggestions for improvement. A few of the roughly 50 responses are given here:

“I benefited a lot from the school. And overall the experience was invaluable. My criticism was that I sometimes felt that the emphasis was too heavily based on getting results (namely graphs of numerical simulations) rather than education. I found this a little bit stifling because I had open-ended ideas that I wanted to explore. And I know that the help of the staff in developing these ideas with would have been very educationally valuable to me. But, towards the end I was strongly encouraged to do things that I already knew how to do, which had less educational benefit to me.”

“The GFD program is a great educational experience which introduces many talented future scientists to our field. We should make every effort to make sure it continues for many generations of new scientists. Adding more visiting lecturers can be beneficial to all.”

“The GFD faculty was, taken as a group, as good as or better than the best department anywhere. It was a real treat to be a student/fellow of this group.”

“The most valuable lesson for me was watching this accomplished group 'do science'. I learned more from interacting with them, and watching/listening to them interact with one another and with other fellows than from any specific problem or piece of research.”

“I chose the wrong project with the wrong advisor. I didn't get much out of the summer. But, in a different situation, I definitely would have.”

The Dean's office also has the fellows evaluate the program, and many comments are similar to those given above. A particular one from this year is “Busse: very good and interesting lecture – What a privilege to hear all this stuff from the great man himself!”

## **TRANSITIONS**

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 although individual staff members often remain involved with the fellows' continuation of their projects past the end of the summer. Many staff work on their research while in residence.

## **RELATED PROJECTS**

All staff members are active research workers, so numerous related projects exist.