

Woods Hole Oceanographic Institution: Informal History

Preliminary remarks

The following account includes a description of events that took place before the GFD/WHOI program existed and that led to the establishment of the program. That is followed by an informal discussion of the program that was accumulated by George Veronis over the years. It is not a history of the program but rather one person's summary of experiences over the past 54 years in the program. My hope is that others will send in corrections or additions so that gradually a more complete story of the GFD program will emerge. Any potential additions should be sent to Janet Fields, who will transmit them to me for editing and insertion in the record.

Informal account

There were several different sets of circumstances that led to the establishment of the summer program in Geophysical Fluid Dynamics at the Woods Hole Oceanographic Institution (WHOI).

In September 1957, I attended the IUGG meeting in Toronto along with Pierre Welander from Sweden. He and I had dinner one evening with an agent of the Swedish equivalent of the CIA and were told by that agent that the Soviet Union was about to launch an artificial satellite and that they would try to do so during that month to commemorate the 100th anniversary of the birth of a Russian pioneer in space science. At that time even the thought of an artificial satellite seemed preposterous, and both Pierre and I wrote that off as a Buck Rogers scenario dreamed up by unrealistic counterintelligence people. When I returned to Woods Hole, I told Hank Stommel and Willem Malkus about what we had heard, and they agreed that it was not to be taken seriously. The month of September passed without a launch and it seemed that our skepticism was justified. But early in October Sputnik was put into orbit.

It must be difficult for younger people today who have got used to a steady stream of unannounced satellite launches to imagine how astounded the world was to see Sputnik orbiting in space. Scientists and engineers the world over were deeply impressed by the unanticipated achievement of the Soviet Union. No American could understand how the Soviets managed to be the first to penetrate space. The fact that it was true mobilized our entire country. Within a year supporting agencies found that they had funds to support any reasonable proposal to help the U.S. catch up to the Soviet Union. Thus, the funding milieu couldn't have been better.

A couple of years before Sputnik, in the spring of 1955, Hank Stommel had been invited to visit the numerical weather prediction research group that John Von Neumann had set up for Jule Charney to run at the Institute for Advanced Study in Princeton, N.J. Hank and I had known each other since 1952 but his visit to the Institute, where I was working at the time, provided an opportunity to collaborate scientifically. We produced an article on inertio-gravity and Rossby waves in a two-layer ocean. When our group disbanded a year later, Jule moved to MIT together with Norman Phillips and I moved to WHOI to join Hank.

Hank's collegial nature is legend. He was a wonderful person to work with and to be around. The group of theoreticians (if Hank's activities can be restricted to that description for present purposes) consisted of Willem Malkus and me during the winter, but it expanded greatly during the summer when a great variety of people would gather around Hank. When I arrived there in the summer of 1956, Hank's visitors included oceanographers from Sweden, Japan, Germany and Egypt, in addition to American scientists and students. Pierre Welander was one of those visitors.

In the fall of 1956 a biweekly seminar series between WHOI and MIT was initiated. On arriving at MIT Phillips and Charney had established contact with Ed Lorenz and other meteorologists there and with the fluid dynamical (applied mathematical) community at MIT, which included C.C. Lin, Lou Howard and J.T. Stuart, who was visiting from Great Britain. Howard, who became an assistant professor in mathematics at MIT in 1955, had been a graduate student in mathematics at Princeton, where we had first met. It was this group of scientists who formed the MIT contingent that took part in the MIT-WHOI seminars regularly. On the WHOI side Stommel, Joanne and Willem Malkus, Fritz Fuglister, Bill Von Arx and his graduate student, Alan Faller, and I were regular participants. Occasionally, at MIT we were joined by Melvin Stern and Ray Wexler and other staff members at the Air Force Cambridge Research Center. During that first year of the seminar we were fortunate to have as a visitor to WHOI Carl-Gustav Rossby, who also took part in the seminar series. Occasionally, George Carrier, Sydney Goldstein, Harvey Greenspan, and Max Krook would come from Harvard to attend the seminars when they were held at MIT.

The seminar, together with the dinner that took place afterwards, served as a focus for a great deal of active and enthusiastic discussion. The seminar was scheduled for two hours and interruptions to make valid points or to ask for clarification were encouraged. There were heated scientific arguments and a great deal of talk during the drives from one institution to the other (the visiting institution provided the speaker). The two-hour (in those days) drive probably served to winnow the participants down to those who were really interested and dedicated. Each group heard stories about how his colleagues in the other group drove. Ed Lorenz, normally quiet and polite, was known to become aggressive behind the wheel. Jule Charney's speed was said to be inversely related to his concentration on the subject of discussion, particularly on the way home after some drinks. Hank Stommel drove an old 1949 Ford at a speed that was painfully slow. Rossby was once a passenger in Hank's car and when Hank apologized for the length of time that the drive to Cambridge had taken, Rossby said, "Don't apologize, Hank. It seems like only yesterday that we left Woods Hole." (A few years later, when Hank had bought a new car, it was clear that he had a new gas pedal.)

The MIT-WHOI seminars led not only to collaborations, but also to interest in issues of development in the fluid dynamics of the

earth's atmosphere and oceans. Lou Howard, in particular, became intrigued by many of the questions, both theoretical and observational, facing oceanographers and spent time at WHOI during the summer starting in 1957. He even took part in some observational cruises, but apart from his own research, he mostly provided mathematical advice on problems that students from the institution's summer programs needed help with.

Starting in 1953 Willem Malkus' theoretical and experimental efforts in turbulent convection had progressed to the point where Willem had a stream of visitors who had heard of his innovative views on thermal turbulence. Willem and his wife, Joanne, spent a sabbatical year in England, where Willem joined the relatively new fluids group under George Batchelor at DAMTP in Cambridge and Joanne became involved with the meteorological research activities at Imperial College. Whether it was the result of his Cambridge connection or the work itself, Willem's progress induced Chandrasekhar to visit him at Woods Hole. Chandra had already carried out a large number of stability studies on thermal convection with and without a magnetic field and/or rotation. These were later summarized in his book, *Hydrodynamic and Hydromagnetic Stability*. He came to Woods Hole to discuss with Willem the types of alterations that would be induced by nonlinearities and turbulence.

That connection with Chandra was very helpful in expanding the sphere of interest in fluid dynamics to astrophysical phenomena. In 1957 Ed Spiegel, who at that time was an astrophysics graduate student at U. Michigan, visited briefly to talk to Willem about problems in thermal convection in stellar atmospheres and to Willem and me about the work on finite amplitude thermal convection that we had just completed. His visit may have been the result of Chandra's earlier contact. After that, Ed became a regular summer visitor to WHOI and provided a continuing expanded focus on the application of fluid dynamics to natural systems and, in particular, to astrophysical phenomena.

Another person who entered the picture at this time is Melvin Stern, who had earlier collaborated with Joanne Malkus, Willem Malkus, Michael Longuet-Higgins and Hank. He left the Air Force with a new PHD acquired from MIT to join the staff at WHOI in 1957.

There was an active program of summer fellowships at WHOI in those years before the joint program with MIT was established. A number of the students worked with Hank and his visitors. One of the latter was Ken Wilson, whom we tried to talk into taking up research in physical oceanography but who decided to focus on physics. He was awarded the Nobel Prize in Physics in 1982. Wilson was an exception, of course, but the quality of the summer students was very high.

Since physical oceanography was a relatively unknown science in those days, summer visitors to the theoretical group, both students and staff, mostly had backgrounds in math and physics and were unacquainted with the kinds of questions that were of interest to those of us working with the fluid dynamics of the ocean and the atmosphere. The effects of stratification and, in particular, rotation, on fluid flows introduced unfamiliar types of behavior. Students, and even some of the visiting senior people, had to gain familiarity with these special effects before they could understand flows in the ocean and the atmosphere. We were all working with physics that clearly had a body of principles in the stage of development and often had a control over the flow that we were still not entirely familiar with.

As an example of how much we had to learn, I cite the story that Alan Faller still tells about an incident at one of the MIT-WHOI seminars at which Faller was speaking. He had just described an observation that he had made about the vertical uniformity in one of his rotating tank experiments when Jule Charney expressed doubts that that result was real. One of the other listeners leaned over and said to Jule, "Of course, it's a real effect," upon which Jule called out, "I'll bet you ten dollars that it isn't!". The other person got up and derived the Taylor-Proudman theorem as proof. (I'm not sure that the theorem had that name in those days.) Jule was, arguably, the leading expert on rotating flows in those days, but that simple theorem had not yet become familiar as the lowest-order approximation for rotating, homogeneous flows.

Certainly the most significant applied mathematical contribution to rotating flows at that time was George Carrier's introduction of singular perturbation theory (boundary-layer techniques) to models of oceanic flows. Although the physical results of simple circulation models, such as Stommel's demonstration of westward intensification as the cause of the Gulf Stream, were familiar and reasonably well understood, the use of boundary-layer methods led to much simpler derivations and, therefore, to overall progress that would have taken much longer without those methods. They were extremely useful as a teaching tool since they made it possible to break complicated flows down into simpler components that could be analyzed and then coupled.

Among the people who helped to create the proper milieu for the development of the MIT-WHOI series was Columbus Iselin, who was interim director at WHOI and who more or less controlled research funding. I don't remember ever seeing him at any of the seminars but he understood what we were trying to do and he encouraged it. He made it possible for us to gather in Challenger House after the seminars in Woods Hole where we made arrangements for dinners cooked by Ida Söderlund, a Swedish woman who had lived in the Woods Hole area for 40 years. Those were also the days of some pretty heavy drinking after the seminars, mostly stiff martinis before dinner. I still marvel that we didn't all die off in auto accidents after those seminars, but there was never a single accident that I can recall. And finishing off the dinner with a good cigar was the norm.

As a director Iselin was a benevolent dictator. He had started out as an oceanographic observer on the Atlantis 1 and ran the important war effort at WHOI during WWII. In the mid-to-late '50's he was an interim director who had a sense of what projects to support from a blanket ONR grant that WHOI still had available. We didn't have to worry about funding and could concentrate our efforts on research. Although he was not the director when we started the GFD summer program, he had certainly laid the groundwork by hiring the staff that developed the program and by supporting the research activities that led up to it.

Iselin had an adjunct professorial appointment at Harvard where he would lecture on physical oceanography occasionally. One of the students who took his course was Allan Robinson, whom Iselin directed toward the theory group at WHOI in 1957, and who decided to do his (physics) thesis on an oceanographic topic. Robinson's thesis advisors were Stommel and Malkus so he was a regular visitor to WHOI in 1957 and 1958 and spent those two summers at WHOI.

When we were coaching summer students on rotating, stratified flows, it became evident that there was a body of knowledge that each of us kept repeating. We talked a great deal about those duplicate efforts and encouraged each other to do something about it - to set up a formal course of instruction so that we could more efficiently give these bright young scientists a good background in what we eventually called gfd. Though Robinson and Spiegel were students themselves, they took part in those discussions. In addition to the need to attract young people to a research institution that had no normal supply of students, the factors that made it possible, and desirable, to set up a formal program were the blanket ONR funding administered by Iselin that enabled us to work without having to raise funds, the rather clear need for a summer course that could provide training of a type that was not in the curricula of universities, and our feeling that we had to do something to offset the discouragement that we all felt about having fallen behind the Soviet Union in the race to space. We benefited, too, from that wonderful, invincible feeling that youth has - that we could do anything that we set our minds to. Stommel, the oldest of the bunch, was 36 years old in 1956.

A year after Sputnik, in the fall of 1958, I wrote the first draft of a proposal for a GFD summer program and submitted it to Paul M. Fye, who had just become the new director of WHOI. I still have a copy of that first draft entitled "WHOI School for Theoretical Studies in Geophysical Hydrodynamics", in which Willem, Hank and I were to give the principal part of a course that was to last three months. In the next draft the course length was reduced to 10 weeks and the title became "Summer Program of Theoretical Studies in Geophysical Fluid Dynamics". Of course, there was a good deal of discussion with potential participants and with the WHOI administration so it was not until 31 March, 1959, that a final draft was sent to NSF along with a transmittal letter from Paul Fye to Raymond Seeger, who was Assistant Director of NSF, stating:

Dear Raymond:

Some time back when I visited with you at the National Science Foundation you said that the Foundation was willing to support courses, particularly in areas of science that need expansion. It has occurred to us in Woods Hole that the proposed course by Malkus, Stommel and Veronis, as described in the enclosed proposal, would perhaps merit support by the National Science Foundation. We have given a variety of courses in the past but this is aimed at a considerably higher level than the previous ones. It is an experiment we are anxious to undertake. Would you be good enough to see that it gets into the right hands?

Best regards, Paul M. Fye, Director

The entire budget page consisted of:

	<u>One Year</u>	<u>Three Years</u>
WHOI Staff	N/C	N/C
Guest Lecturers (2)	\$ 1,500	\$ 4,500
Postgraduate and graduate student		
fellowships (5 or 6)	8,500	25,500
Indirect Costs at 15 %	<u>1,500</u>	<u>4,500</u>
TOTAL	\$ 11,500	\$ 34,500

The proposal was immediately accepted and the program was launched (just 10 weeks later!) on 15 June, 1959. Joanne Malkus had hired Mary Thayer, who turned 65 in 1956, as a kind of all-around assistant on her meteorology project. When the GFD program started, we acquired Mary as our secretary. She was then 68 years old and she drove 18 miles each way from Osterville to Woods Hole for the next 20 summers until her retirement in 1978 at the age of 87.

Mary was remarkable. She liked running the program and even let us think that we ran it. She did all of the typing for the course. That was quite an achievement because the fellows would leave on the last day of the program and Mary would then type all of their notes of the lectures and their reports from their handwritten manuscripts, filling in the mathematical equations. She was known to correct some of the equations, although sometimes her corrections raised eyebrows. The fellows would hand her their notes of each day's lectures and she would have them typed and distributed within a week after the lectures. The summer report would be sent to us by the end of October. Nowadays, with all of the computer resources and willing fellows, the lectures and reports become available in one volume about 15 months after the program ends.

Mary's contributions were not restricted to typing. As an old Yankee she felt it was her duty to correct the manners of anyone, particularly New Yorkers, who appeared to her to need proper training in how to behave. She was a terrific gossip, as was Hank Stommel. Between the two of them we were kept informed about all of the important things that went on around the Upper Cape. She was also a staunch Republican, who never failed to express her disdain for those upstart Kennedys who had moved into Hyannisport and who, after Kennedy became president, were responsible for the loss of tranquility in the area around Osterville.

The first summer program included four student fellows and six invited staff, in addition to the WHOI members, and the stated purpose was to formulate tractable problems in gfd which would be the focus of the fellows' research activity. Most of the summer was taken up with lectures, actually seminars, on stuff that we were working on. Our lectures were modeled on the MIT-WHOI seminars. It never paid to prepare a two-hour lecture with the expectation of getting to the end. The practice of having free-wheeling lectures has continued to the present day. At that first summer I remember struggling to present the Boussinesq approximation, which all of us used but which had not been clarified by rigorous derivation. After I failed to obtain a consistent derivation by the end of two lectures, Thomas Phillips, one of the fellows, drew a sinking ship with a caption that used the words that I had been repeating, "The ship of gfd slips below the surface of a nearly incompressible, shallow layer of water".

Robinson and Stommel talked about their recently derived thermocline theory, Willem Malkus about turbulent convection, Joanne Malkus gave a week on cloud physics, Bob Kraichnan presented his direct interaction approximation for the study of turbulence, and Arnold Arons reviewed aspects of underwater acoustics. Alan Faller showed the laboratory simulation of ocean circulation in a pie-shaped basin which he, Stommel and Arons had developed. We were feeling our way in the beginning and no formal record was kept of the lectures or of the fellows' reports of the first summer. Willem was the director. Paul Fye had asked me to be the director since I had written the proposal but I told him that I thought that the director should be a full staff member rather than an associate member. I had hoped that he would raise me to full staff member status so that I could be the program director, but that ploy didn't work.

At that time essentially all of the scientific activity at WHOI took place in two buildings, Bigelow and Smith. We made use of the lecture room in Smith but otherwise the program was housed in Bigelow. Spiegel and I were squeezed into my attic office in Bigelow.

There was no organized GFD softball team in the beginning. I had played on a WHOI team from the time that I arrived in 1956 and continued to do so. A regular GFD softball team each summer was not organized until sometime later. Playing softball together turned out to be one of the fastest and most effective ways of lowering the barrier between staff and student that normally exists when one group is required to evaluate or certify another. Striving against external opposition on the ball field served to generate the *esprit de corps* that comes with working toward a common goal; that cooperative feeling flowed smoothly from ball field to classroom to research project. In addition, playing together led to a very quick bonding among the fellows each summer and continues to do so.

At the end of the 1959 program Hank Stommel became a professor at Harvard, which had courted him for a year or so. The fact that he did not have a PhD had always bothered him (to the point where he freely bestowed the title Dr. even on graduate students), and he felt that training PhD's at a prestigious institution would make up for that. It was an enormous change for Hank, who was very familiar with the environs of Woods Hole and who made extensive use of the MBL library at any time of the day or night. He moved to Concord with his family but he was not happy living away from the cape and WHOI and he didn't really like being a professor at Harvard. He kept his house in Falmouth and planned to spend his summers there and to work amongst his old oceanographic colleagues at WHOI. He decided that oceanography was what he really wanted to do and that, although he would keep contact with the GFD program, he would not be intimately involved with it. Three years after his move to Harvard, he accepted a professorship at MIT where he felt much more comfortable. At that time he decided to move his family back to Falmouth and to commute to MIT.

For GFD60 Willem asked Lou Howard if he would prepare a more structured course in fluid dynamics and develop the modifications associated with rotation in a systematic way. At the same time he prevailed upon WHOI to support some GFD students so that a total of 9 fellows attended the 1960 course. In addition, Harry Wexler, the head of research in the U.S. Weather Bureau, attended the course and asked to be treated as a fellow. Willem instituted a more stringent requirement of the fellows: they were to give a one-hour report at the end and submit a written project report which, along with the typed notes that they had taken of the (two-week-long) lectures, would be part of a record of the program. That requirement has been part of every GFD program up to the present. As a tribute to Willem's efforts, Hank Stommel created the dragon logo, which has adorned all of the volumes, the GFD stationery and countless T-shirts.

The strain of giving an oral presentation and then compiling a written report was too much for two of the fellows and they withdrew without complying. After that summer more care was taken to make sure that the progress of every fellow was monitored often enough to ensure successful completion. Working on one's own problem and then producing a report on it is evidence that a graduate student has been able to make the transition from learning by taking courses to learning by actually carrying out research. We have considered that to be the trademark of the GFD program. The procedure seems to work best with graduate students at the end of their second year of

graduate study when they have had the basic courses in physics and math.

Malkus accepted a professorship at UCLA after the 1960 summer program and I became director for GFD61. (Except for one year, Willem and I alternated as director every two or three years until 1979.) Of the nine fellows that year two were from Norway, two from England and one from Canada. Willem's close connection with George Batchelor resulted in a regular stream of summer fellows from DAMTP at Cambridge, of which D.H. Peregrine was the first. Another first was a weeklong microsposium in the middle of the summer with Nick Fofonoff talking on energy transformation in the ocean. Pierre Welander began his nearly yearly pilgrimages to GFD that year.

Two very significant advances in gfd took place that summer. At the beginning of the summer in a search for a mechanism whereby we could introduce the fellows to the possible areas of research in which they could receive help from the staff, we asked each staff member to list the areas in which he could offer assistance. Lou Howard wrote "anything but turbulence". A few weeks later he gave a seminar on upper bounds in turbulent flows. He had posed the variational problem of finding the heat flux that was consistent with the constraints provided by the kinetic energy and internal energy integrals. The article that resulted from his talk introduced the field of upper bound theory that is actively pursued to this day.

The other advance resulted from the work of Derek Moore from Bristol, who was considered a fellow but certainly qualified as staff. He carried out a very nice analysis to show that an eastern boundary current could not exist as a stable boundary layer in a homogeneous ocean with a Navier Stokes form of friction. The issue had been a confused one prior to Moore's analysis; he laid it to rest.

GFD61 was the last summer in which the title of the course was listed simply as geophysical fluid dynamics. The program had already achieved sufficient stature to attract excellent students from around the world and many of those had some background in some aspect of gfd. Therefore, after 1961 a central theme was chosen for the two-week lecture series (2 hours a day for 10 days) and the program was described by that theme. The next five programs were advertized under the headings: Topics in Astrophysical Hydrodynamics, Rotating fluids, Turbulence and the rotational constraint, Dynamics of Rotating and Stratified fluids, and The Figure of the Earth.

Sometime after Harry Wexler took part in GFD60, he cited the program in a speech before congress and the GFD program was entered into the congressional record. An immediate result and benefit of that was that NSF suggested that we henceforth seek support from their recently established Advanced Training Projects program, which was under the aegis of Alice Withrow. We enjoyed that support until Nixon abolished that section of NSF in 1971.

It had become clear to all by the end of the 1961 summer that the gfd program was a desirable addition to the research activities at WHOI. As a result, Paul Fye suggested that the 1962 program move to more permanent quarters. We were given Walsh Cottage, a small house on WHOI grounds that had gone unused for years. Walsh was the man who developed the rambling rose, which often adorns corral fences. A lecture room, large enough to hold some 40 listeners, was added on to that cottage and we have been housed there ever since. The size of that building has served to limit the program to a size that we consider optimal for interaction.

While we were experimenting with the program during the first 4 or 5 years, a core of dedicated staff was also emerging. What was needed was committed people who would consider WHOI-GFD as a constant factor in their planning each year. It was not difficult to entice people for a year, but to get a long-time commitment was another matter. At the beginning of 1964 I left WHOI for MIT and 6 months later Melvin Stern moved to URI. Therefore, by 1964 none of the original GFD staff was left at WHOI. That summer we discussed the future of the program and how much each of us was prepared to commit to a long-term connection. We formed the GFD Steering Committee: Lou Howard (chairman), Willem Malkus, Ed Spiegel, Melvin Stern, Hank Stommel and George Veronis. Hank was willing to serve as advisor but did not want to identify with GFD. Although we didn't try to get a pledge from each person that WHOI-GFD would be a firm part of his future, it was taken for granted that that was the case. A participant whom we considered to be a really desirable candidate was Pierre Welander, but Pierre could never commit himself to anything for a time longer than a semester. The following year Joe Keller visited the program and made a commitment to return for the summer every other year. He became a member of the steering committee. It's remarkable that the original steering committee has remained part of the program until the present time. There have been hiatuses, such as Lou's withdrawal when he moved to FSU in 1984 but he returned a decade or so later and still takes part. Henry Stommel died in 1992 and Melvin Stern passed away in 2010. Willem's health has kept him from taking part as regularly as he had but he still makes an occasional appearance. On the other hand, Joe Keller has come every summer since his official retirement from Stanford in 1993. (Joe was forced to retire because he turned 70 on the day before mandatory retirement was abolished.) Ed Spiegel and George Veronis still attend the program each summer. Lou has congestive heart failure which limits his ability to attend the program as often as he would like.

On the whole, our experience with the funding agencies has been very positive, although there have been a few glitches. In 1977 our principal NSF contact was the program director for meteorology who was evidently totally unsympathetic to GFD (he had been turned down when he had applied as a graduate student). In April he told me that we had received support for long enough and we should expect nothing more from NSF. Fortunately, Joe Keller contacted Ralph Cooper of ONR, who had the opposite attitude and, in one weekend, scrounged up enough relatively small amounts from different sources so that we could operate in 1977. A couple of years later NSF approached us and asked why we had not sought support from them for a time and offered to reinstate us as deserving candidates.

As time went on, when we were trying to raise funds for a particular period, we were told by NSF that we should add younger people to the steering committee and train them to take over when we stepped down. We had been accused for years of running an old

boys' club. It's fair to say that those who urged these changes on us were unaware of the need for continuity. We never had trouble getting people to commit to one summer. It was difficult to get more than that. Although Rick Salmon and Neil Balmforth have been truly successful in making the commitment and continuing the program, that had not been the case with most of the others whom we tried to incorporate into the system. For one thing, it's much easier to make a commitment to something that one has created oneself. Those who step in may be willing to commit only for a single year. We have had several single-year directors who have done a good job and then left and others who have been willing to lend only their names to the steering committee.

A few years ago we gave up trying to recruit members for the steering committee with more or less permanent commitments to the program and instead have formed a "faculty" of about 25, listed below, which helps to choose topics for each of our five-year proposals and from which a director is chosen each year. Neil Balmforth, together with a rotating group of faculty members, provides the needed continuity by submitting five-year proposals to NSF with topics chosen by the faculty.

More or less by accident, the GFD program is financially independent of WHOI. In the beginning all of the founding members were part of WHOI. After their departure the support provided through the Advanced Training Projects of NSF gave GFD a separate identity and the continued success in obtaining support from NSF each year has kept the program financially independent. However, the program is listed as part of the educational effort by WHOI, which provides secretarial help during the summer, maintains the physical facility and helps to administer the program during the off season, serving as a clearing house as arrangements are made for the following summer. These are crucial activities that could not be carried out by a nonresident group.

Though the primary financial support for the operation of the program comes from the National Science Foundation and the Office of Naval Research, an endowment from the Henry Sears Foundation (this is the son of the JMR Henry Sears) provides an income, which supports special participants and activities that are not financed through the government agencies. An example of such an activity is the annual public lecture sponsored by the Sears Foundation. A contribution from Neil Balmforth supports one fellow each summer.

One direct benefit that WHOI has derived from the presence of the GFD program is that twelve current or former WHOI faculty in physical oceanography are alumni of the GFD program.

The names and current affiliations of the 465 fellows who have attended the program up to the end of GFD2010 are given in the Appendix at the end of this account. The current addresses change continually but the general identification of type of activity remains relatively constant four or five years after participation in the program. About 85% of the fellows in the program have ended up in either academia or government research labs.

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