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A Biographical Memoir by

CARL WUNSCH

Biographical Memoir

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BY CARL WUNSCH

HENRY MELSON STOMMEL, probably the most original and important physical oceanographer of all time, was in large measure the creator of the modern field of dynamical oceanography. He contributed and inspired many of its most important ideas over a forty-five-year period. Hank, as many called him, was known throughout the world oceanographic community not only as a superb scientist but also as a raconteur, explosives amateur, printer, painter, gentleman farmer, fiction writer, and host with a puckish sense of humor and booming laugh.

Stommel entered oceanography when the field still had much of the atmosphere of an avocation for wealthy amateurs who used their own yachts for research; he left it at a time when it had been transformed into a modern branch of science, often driven by perceived needs of national security, and of global, organized, highly expensive programs requiring massive government funding. In a sociological sense he was a transitional figure, being probably the last of the creative physical oceanographers with no advanced degree, uncomfortable with the way the science had changed, and deeply nostalgic for his early scientific days. The paradox of his life is that the huge changes that had taken place were to a great extent of his own making, and are a testament to the major advances his ideas had made possible. He was a man of deep ambivalences and contradictions. He sometimes recognized, but often did not, that his intellect was driving him and the study of the ocean in one direction—toward the use of modern sophisticated instrumentation and computers and to the organization of giant field programs—while his heart clearly lay with the science of his youth, which involved intense work at sea with gifted amateurs and crusty old fishermen using primitive instruments made by clever local machinists and craftsmen. All of his personal inclinations led him to identify most closely with the large group of "amateur" scientists who represented oceanography in the years just following World War II. They and their successors, despite their having doctoral degrees, came closest to representing what he loved: serious observational work at sea by close teams of like-minded, unpretentious people. His writings and talks are full of contradictions: exhorting fellow scientists to eschew organization and bureaucracy and get to sea, while simultaneously complaining that the science was being strangled by the focus on purely local problems, inadequate theory, and poor instrumentation, the remedy for which was professionalism and large-scale organization.

Stommel was born in Wilmington, Delaware, on September 27, 1920, into what today would be labeled a dysfunctional family. His ancestors were from the Rhine Valley, Poland, Ireland, the Netherlands, England, and France, with a trace of Micmac Indian. Walter Stommel, his father, was a chemist born in northern Germany and trained in Darmstadt and Paris. In the upheaval of the First World War, he emigrated to Wilmington where he found employment with Dupont Chemical. While there he married Marian Melson whose family had lived on the Eastern Shore of Maryland and nearby Delaware since colonial times. Their son Henry

Melson Stommel was born shortly thereafter. For reasons which are not entirely clear, perhaps anti-German sentiment following World War I, the family moved to Sweden, where Walter rose to become chief chemist of a leather factory. But Henry's mother, just prior to the birth of a daughter, Anne Stommel, left Sweden; with Henry she returned to Wilmington, choosing never again to see her husband. (Among other problems, she hated the primitive life in rural Valdemarsvik, Sweden.)

Henry thus grew up in a single-parent family. Although he states in his autobiography that he did not know his father was alive (and with a second family) until he entered high school, it is clear that Henry and Anne exchanged Christmas cards with him from a very early age (E. Stommel, private communication, 1995).

In 1925 Henry's mother moved with the two children to Brooklyn, New York, where the household consisted of Henry, his sister Anne, and their mother, but also included their maternal great-grandmother, a divorced Aunt Beck and her daughter, and a maternal grandfather and grandmother. As described by Henry, the household was supported wholly by his mother working as a fund raiser and public relations officer for a hospital (this was during the depression) and dominated by female disputation. His grandfather, Levin Franklin Melson, was apparently a peaceful man who retreated upstairs to his room. The discussions he and Henry carried on there until Melson's death, when Henry was eleven, provided a refuge for both of them. Melson was an important person in Henry's early years. He had been trained as a lawyer, worked as a bank clerk, struggled with alcoholism, but apparently had a true love of knowledge and a bit of scientific understanding, including a taste for simple chemistry and *Popular Mechanics*. Science was both interesting and a protection against the discords of the world.

EDUCATION AND EARLY PROFESSIONAL YEARS

Stommel's education was in the public schools of New York City at a time when that system had many highly educated, articulate teachers who had sought security during the depression through careers in public education. He spent one year at the competitive-entry Townsend Harris High School, but finished high school at Freeport, Long Island, where the household had moved. He proceeded then to Yale University largely on the basis of his mother's successful efforts to obtain a full scholarship for him. There a major in astronomy failed to provide a focus for his interests. Graduating in 1942 at the height of the Second World War, he was faced with a conflict between his basic pacifism and self-awareness of a streak of aggression; he compromised by remaining at Yale for two years teaching analytic geometry and celestial navigation in the Navy's V-12 program. Six months spent at the Yale Divinity School showed that the ministry was an unsuitable vocation (he had a lifelong ambivalence towards religion, organized or otherwise). In 1944, at the suggestion of the well-known astrophysicist Lyman Spitzer, he applied for work at the Woods Hole Oceanographic Institution in Woods Hole, Massachusetts, an organization that had been transformed rapidly from a summer-only field station into an arm of the U.S. war effort. Assigned to work with Maurice Ewing on acoustics and antisubmarine warfare, he found both the work and Ewing's imperial style quite unpalatable. He escaped as quickly as possible into other groups and endeavors.

Stommel flirted with a number of different aspects of physical oceanography during the period immediately following the war. These included a major effort on modeling tides, atmospheric convection, Langmuir cells, and speculations about computer possibilities, but he did nothing that either he or his supervisors regarded as particularly noteworthy. Then, almost "out of the blue," he published a paper (1948) that marked the birth of dynamical oceanography and the start of his continuing avalanche of new ideas over the next forty-five years. During these early years he was fortunate to have encountered a few individuals who acted as mentors and advisers. These included Lyman Spitzer at Yale, who sent him to Woods Hole; Jeffries Wyman, who put him on to the theory of convection and remained a good friend thereafter; and, especially, Carl Rossby, who inspired him.

Stommel remained at the Woods Hole Oceanographic Institution (WHOI) until 1959, when he left to become a professor at Harvard University. He clearly loved WHOI and the life of the small town of Falmouth. His departure was the culmination of a deep-seated antipathy for the director (Paul Fye) and his policies, coupled with the lure of being a professor at an institution with the reputation of Harvard University. (A significant number of the best scientific staff at WHOI also left around the same time.)

The four years he spent at Harvard were clearly distasteful and unhappy (he wrote about this time in some detail in his autobiography, which was published posthumously[1]) and he "fled" to the much more congenial and democratic environment in the Department of Meteorology at the Massachusetts Institute of Technology (MIT). There his closest colleagues were to be people such as Jule Charney, Norman Phillips, Edward Lorenz, and Victor Starr. The major problems at Harvard (his departure was something he continued to rationalize for many years) appear to have been the arrogance of both the institution and of individuals there—which clashed with his deeply democratic instincts—coupled with a sense of not belonging in such a place without a proper doctoral degree.

Stommel worked at MIT for sixteen years as professor of physical oceanography, returning to WHOI nearly instantly upon the retirement as director of his *bête noire*, Fye. He remained there actively doing science almost to the day of his death, only rarely and grudgingly leaving Cape Cod. Some of his most interesting work was done toward the end of his life.

Stommel married Elizabeth Brown, daughter of Huntington Brown, professor of English at the University of Minnesota, and Elizabeth Waldo Wentworth Brown, originally of Boston, on December 6, 1950. They had three children: Matthew (a professional fisherman in Falmouth, Mass.), Elijah (a physician at the Dartmouth-Hitchcock Medical Center), and Abigail Stommel Adams (a nurse practicing in Falmouth). Hank's devotion to his wife (universally known as Chickie) was complete, manifested in part by his insistence every day, when it was humanly possible, on bolting home for lunch precisely at noon. Her own work, apart from the family, has been as a writer, church organist, and hospital chaplain.

Henry Stommel's work can be divided crudely into several overlapping categories. The Collected Works contain expert commentaries on his work, and I will therefore simply summarize the high points. A general comment is that he made observations at sea, designed (with the help of talented engineers) new instruments, worked in the laboratory (again with the assistance of skilled experimentalists), and did theory. The work of such a person is not easily summarized. I do think it fair, however, to assert that his sea-going was important mainly for the inspiration it gave him, rather than for the power of the data per se. He was not temperamentally suited to the infinite taking of pains reflected in the very best at-sea work, which he so admired in others.

THEORY OF THE GENERAL CIRCULATION OF THE OCEAN

The general circulation of the ocean was the focus of Stommel's efforts for decades and our present understanding of it is his greatest monument. In this field as in the rest of his science he combined a deep, sometimes wholly inexplicable, physical intuition with a love of field work and just enough mathematical skills to suit his needs. Constantly complaining about his lack of mathematical abilities, he always found either the precisely right, just-simple-enough problem or a suitable, more mathematically adept collaborator to generate a series of papers that constitute a history of oceanographic theory and observation in the middle to late twentieth century.

This body of work begins with the 1948 paper already mentioned, in which he showed that the Gulf Stream was a phenomenon that could be explained deductively by fluid dynamics. In particular, he found the mechanism (the latitudinal change of the Coriolis force on the rotating Earth) that produced the westward intensification of oceanic currents. This first paper is prototypical; he fingered an essential phenomenon, which somehow no one had ever thought to try to understand, and he then formulated an extremely simple model that was reduced by him to nothing more than a linear two-dimensional partial differential equation whose solution provided the essential insight. There is a long list of powerful and sophisticated scientists who must have kicked themselves for not having seen the problem and its mathematically easy solution.

This paper is also prototypical of his approach to finding problems to work on. Stommel attributed to the late Raymond Montgomery the suggestion that the Gulf Stream was something important and in need of explanation. (But Montgomery attributed it to Columbus Iselin.) On completing a piece of work, Stommel would go searching for something to take up next; he relied on colleagues to an astonishing degree, given his creativity, to point him in new directions. He roamed the corridors of MIT and WHOI, asking in effect, "what's interesting?" Often he would get intrigued, hooked, and would become obsessed with a problem to the point where he was preoccupied with it day and night. More than one collaborator can attest to the late-night or 6:00-a.m. phone call that would start without so much as "hello," but would come out something like "you know I think the second term in that equation can be neglected, because..."

In the decade following the 1948 paper, Stommel and his collaborators had gone from a primitive and stumbling beginning to a sophisticated theory of the thermocline, the gross thermal structure of the ocean (1959), to a theoretical view of the global abyssal circulation (1960). His important book, *The Gulf Stream*, had already been written by about 1954 and was probably the first true dynamical discussion of the ocean circulation. He embedded the Gulf Stream in the wider context of the general circulation and already clearly had in mind what became the so-called thermocline theories. Following these theories of the late 1950s and early 1960s, there was an extended pause in the theoretical work of Stommel and of others; the theories were based on similarity solutions to an otherwise intractable set of nonlinear partial differential equations. They were a considerable, almost astonishing achievement, a clear beginning on a full theory, but were very difficult to work with and their extension obscure. For a long period ending in the early 1980s Stommel's attention turned to more specific elements of the general circulation. The results included an important paper pointing out the great significance of the very small area in which the ocean underwent convective sinking; a study of the balance of forces in the

Antarctic Circumpolar Current;[2] a series of studies of the nature of convection in the Mediterranean; and in 1979 the introduction of the important concept of the "Ekman demon," which opened the new field of ocean subduction. During the period from about 1963 to 1980 his focus on the general circulation was largely observational (discussed below).

Then in 1983 Luyten, Pedlosky, and Stommel reopened the study of the oceanic thermocline structure through the seemingly ruthless means of replacing the equations for a continuously stratified fluid by those for one constructed of layers. This simple step, coupled with a highly developed physical intuition, suddenly made the study of the oceanic thermohaline structure blossom once again; this paper was followed by a torrent of papers by Stommel and collaborators, as well as many others. Although this theoretical vein may now be nearly mined out, Stommel had clearly rejuvenated, late in his career, the study of a fundamental problem in oceanic physics.

OBSERVATIONS OF THE OCEAN CIRCULATION

Henry Stommel was constantly looking at data, his own and that of others, speculating about possible new instruments and incessantly planning expeditions around the world. The advent of modern long-endurance oceanographic vessels, electronic instrumentation, and the appearance of jet passenger airplanes beginning in the early to mid-1960s made it practical for the first time to study distant oceans without spending years away from home. (He bemoaned the disappearance of the evocative old oceanographic sailing vessels such as the *Atlantis.* But he confided to me, standing on her deck as she was preparing to leave Woods Hole for the last time on her way to oblivion in Argentina, that the new vessels were far better for serious work at sea.

Similarly, the advent of modern computers and electronic instruments meant that the sort of mechanical devices he liked to tinker with had become obsolete and nearly irrelevant.)

He instigated and participated in many cruises all over the world. The most notable of these were the Swallow-Worthington float measurements that offered confirmation of his abyssal circulation theory; the multiship, multinational studies of Mediterranean convection;[3] the first-ever, true trans-Pacific hydrographic sections; and the wonderfully romantic operations in the Seychelles using the marginal vessel *La Curieuse.* In his autobiography he gives an account of this mode of doing oceanography in a small, exotic, faraway port, using simple equipment and dealing with all the characters one must in such an operation. This was oceanography in the middle 1970s carried out in a style as close as possible to that of 1950, and he loved it. On the other hand, he felt compelled to admit that because of their crude equipment they missed the really important discovery: the equatorial jets found by Luyten and Swallow with a large crew and scientific party using a state-of-the-art profiling device on a modern oceanographic vessel.

Stommel's invention with Fritz Schott of the so-called beta-spiral method for determining absolute flow in the ocean was a high point of this period. Although the method has been used frequently to make estimates of the actual oceanic flow, perhaps its most important result was to demonstrate forcefully that the classical problem of physical oceanography—the inability to determine absolute current at sea from temperature and salinity measurements alone—was, like the Gulf Stream in his 1948 paper, a problem susceptible to theoretical analysis and solution. In a more recent context the beta-spiral is an example, when modified, of an inverse method. It spawned a host of extensions and applications.

By around 1969 Stommel had concluded that the new technologies rapidly becoming available to oceanographers (the invention of solid-state electronics has had a greater impact on oceanography than any other technical innovation of the twentieth century) would make it possible to observe the ocean circulation at sea in a qualitatively new way. Gradually seeping into the oceanographic consciousness was the realization that the ocean was highly time-dependent and probably turbulent—a picture at odds with the prevailing mind-set of a steady, essentially slow, laminar flow. Over the previous twenty-five years Stommel had published a series of exhortative articles urging his colleagues to recognize that one could not understand the ocean by summing up results from a series of small regional experiments. He thought the time had finally come to put into practice the vision he had been preaching. One result, albeit peripheral to his own immediate scientific interests, was the global-scale Geochemical Sections Program (GEOSECS). Another was the Anglo-U.S. Mid-Ocean Dynamics Experiments (MODE) and its U.S.-U.S.S.R. successor POLYMODE, instigated, organized, and overseen by Stommel over many years.

By most measures these programs were a great scientific success (particularly GEOSECS and MODE) and became prototypical of successor generations of organized international oceanographic programs. But Stommel found himself embroiled in bureaucracy, paperwork, meetings, and intellectual compromises in the name of international and national comity, all completely contrary to his taste in science. His return to Woods Hole in 1978 led him to resign from all such programs and thereafter he would serve on no committees or participate in any organizations; he would not even take on another graduate student or postdoc.

MIXING AND MICROSTRUCTURE

Perhaps his most famous experiment was one he deprecated: the study with L. F. Richardson in 1948 of lateral mixing in large bodies of water, using nothing but cut-up parsnips. This work is perhaps the ultimate in the strings-and-sealing-wax school of oceanography, but remains an important achievement in a field that has grown increasingly important over the years. He professed the greatest admiration for scientists who did precisely what he himself did not do: spend long months at sea, making exquisite, high-quality observations. But these scientists (although he did not say this) could not take the intellectual leaps that were his own forte.

The entire field of what is usually called double-diffusive convection is often traced to a one-page paper with the unusual title "An oceanographical curiosity: The perpetual salt fountain." Stommel himself attributed the main idea to his longtime collaborator Arnold Arons, and it was Melvin Stern who later, in 1959, recognized the much more fundamental nature of the phenomenon. (He praised Stern highly for this; clearly he was somewhat chagrined not to have had that insight himself.) Out of these efforts—and with a kind of absentminded, intermittent interaction with collaborators—grew the laboratory experiments and later theories that have developed this field into a branch of fluid dynamics in its own right (J. S. Turner in the Collected Works well describes Hank's approach to laboratory work).

Although Stommel preferred to work with simple instruments (parsnips, buckets of salty water, etc.), he clearly recognized that much more sophisticated measurements were required to understand the ocean. He was always on the lookout for clever new instruments (e.g., early foreseeing and helping to bring into being what became in the hands of Tom Rossby and Doug Webb the SOFAR float, an acoustically tracked instrument that floats at a predetermined midwater depth). Neil Brown by the middle 1960s had produced the first of the revolutionary continuously profiling devices, then called an STD (salinity-temperature-depth). Despite the intense skepticism of many of his colleagues, Stommel determined to use these instruments to study mixing of Pacific and Indian Ocean water in the Banda Sea in the Indonesian archipelago. Somewhat concerned about their reliability, he succeeded in getting three of these new instruments on board the *Atlantis II.* At the very last minute, refused permission by the Indonesians to work in their territorial waters, he proceeded to use STDs on the northwest Australian coast, making repeated surveys of the interleaving water masses. With his collaborator, the late Soviet oceanographer Konstanin Federov (who had become so enamored of the instrument he undertook its virtual single-handed operation), he produced an extremely important discussion of the implications of their measurements. Out of this work, and in the hands of skilled instrument designers and users such as Charles Cox, eventually came the new field of fine- and microstructure studies.

For a long period Stommel was fascinated by the Indian Ocean, mounting repeated expeditions there, often in collaboration with his longtime friend John Swallow. He sometimes tried to work independently of modern oceanographic tools by running small boat operations out of such outlandish (and dangerous) places as Somalia.

TIDES, ELECTROMAGNETIC METHODS, EDDIES, ESTUARIES

Henry Stommel worked on a vast variety of problems. These included tides, pedagogical problems (how to explain the Coriolis force), numerical methods, and internal waves. The breadth of his interest can be understood simply by reading the titles of his unpublished technical reports as listed in the Collected Works. Nonetheless, a number of major foci do stand out. These include the general application of electromagnetic measurements to oceanic flows, the dynamics of estuaries and the related problem of hydraulic controls, and the interaction of nonlinear eddy-like phenomena (hetons). The last category generated in part his late-in-life fascination with computers, machines whose influence he had thitherto found rather distasteful.

ACADEMIC YEARS

Although he was professor for nearly twenty years at two leading academic institutions (Harvard and MIT) he rarely wrote or spoke of his role as teacher. Perhaps his deepest ambivalence emerged here. He was advising students on how to obtain a Ph.D., which he lacked himself. In explaining his presence at MIT, he would admit, slightly grudgingly, that his personal goal of real progress in the field demanded a level of sophistication in mathematics, fluid dynamics, statistics, and electrical and mechanical engineering that was simply beyond the amateurs, although the amateurs were often more fun.

Hank Stommel was not a very good lecturer. He often stumbled, reversing thought in the midst of a sentence—thinking aloud. For strong students who could cope, he was nonetheless a superb teacher in the wider sense—a source of stimulation, ideas, love of the ocean. A number of his

Ph.D. students have gone on to successful careers of their own.

Hank Stommel had a sense of fun in almost everything he did. He clearly enjoyed life and being around people. He wrote incessantly, producing several non- or semi-technical books, including *Volcano Weather: The Story of 1816, the Year Without a Summer* (1983) in collaboration with his wife Elizabeth and a series of brief essays on the passing scene in the *Falmouth Enterprise* under the pseudonym "Starbuck." (The series ended prematurely when the newspaper foolishly disclosed his identity.) He had a taste for the absurd, being fascinated especially with a nineteenth-century character named William Leighton Jordan, who attacked the British Admiralty for allegedly falsifying temperature measurements made on the *Challenger* expedition. Stommel wrote an entire book on islands that never actually existed.[4] He loved making and setting off fireworks for the amusement of his own and visiting children, as well as for himself. There was a period in which he printed newsletters, some anonymously, poking fun at various people and institutions. He built a railroad in his backyard for the entertainment of his grandchildren and visiting oceanographers. His skill as an amateur painter was considerable, sometimes manifesting itself in unexpected ways, such as the kitchen refrigerator he decorated with tropical birds and animals on a brilliant yellow backdrop. The list of his interests in almost endless.

Apart from his own science, Stommel's greatest legacy was his inspiration to others struggling to make their way scientifically. Anybody who would listen became the object of a passionate lecture on what was exciting him and what he was doing, with both parties usually emerging with renewed enthusiasm. He was unassuming, normally unwilling to impose his views on others, and unhappy with bureaucracy and organization. Stommel did, however, have an acute sense of his own worth. In private, and only in private, he could be scathing about individuals who he felt did not treat him with the respect owed him or who he believed had reputations far beyond what their own work merited. But basically he was a kind man who did not want to deliberately make anyone unhappy. If asked to write a letter of recommendation for a person whom he really did not admire, he would nonetheless find some way to say something positive. To Hank's dismay, these letters were sometimes seriously misinterpreted. But even his privately expressed reservations made him acutely uncomfortable. One day one could hear him expressing outrage about what someone had said or done; the next day, seemingly as a form of penance, he would be going out of his way to assist that very same person in a promotion or career advance. Consistency was not his chief virtue; compassion perhaps was.

During his lifetime, Henry Stommel received many honors and awards. Among them were the National Medal of Science, the Craaford Prize of the Royal Swedish Academy (shared with Edward Lorenz), election to the National Academy of Sciences (1959), and foreign membership in The Royal Society, London (1983), the Soviet Academy of Sciences, and the Académie des Sciences de Paris.

I WAS GREATLY ASSISTED in the writing of this memoir by Elizabeth (Chickie) Stommel who agreed to several hours of oral history (the tapes of which will be deposited in the WHOI archives) and the answering of endless questions. Henry's sister, Anne Melson Stommel of Red Bank, New Jersey, who corrected details and who kindly provided an extensive written background on the Melson family history, a copy of which will also be placed in the WHOI archives. The publication of Henry Stommel's Collected Works with his autobiographical essay and the commentaries by a number of individuals was of great help. The autobiography is somewhat "raw"—it was not published in his lifetime—and the reader is warned that Stommel's

memory was not always reliable. I also drew on the personal essays about him in *Evolution of Physical Oceanography, Scientific Surveys in Honor of Henry Stommel*, edited by B. A. Warren and C. Wunsch (MIT Press, 1981). The manuscript was read for accuracy by Elizabeth Stommel, Joseph Pedlosky, Henry Charnock, Anne Stommel, and Nelson Hogg.

NOTES

1. N. G. Hogg and R. X. Huang, eds. *Collected Works of Henry Stommel.* Boston: American Meteorological Society, 1996.
2. An analogy to the Antarctic Circumpolar Current. *J. Marit. Res.* 20(1962):92-96.
3. MEDOC Group. Observation of formation of deep water in the Mediterranean Sea. *Nature* 227(1970):1037-40.
4. H. Stommel. *Lost Islands: The Story of Islands That Have Vanished From the Nautical Charts,* Vancouver: University of British Columbia Press, 1984.

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