BIOGRAPHICAL MEMOIRS

Norman Alton Phillips

July 9, 1923–March 15, 2019
Elected to the NAS, 1976

A Biographical Memoir by Dennis L. Hartmann and John Marshall

Norman Alton Phillips was a leading theorist during the early days of the development of weather and climate models following World War II. He participated in the creation of the first numerical weather prediction models at the Institute of Advanced Study (IAS) in Princeton, New Jersey. He developed the first computer model of the atmosphere's general circulation, a forerunner of the global climate models in use today. He was an excellent teacher and mentor and led the Department of Meteorology at the Massachusetts Institute of Technology (MIT) from 1970 to 1974. Thereafter, at the National Weather Service, he helped develop nested regional weather prediction models and worked to incorporate newly available satellite observations into weather forecast systems.

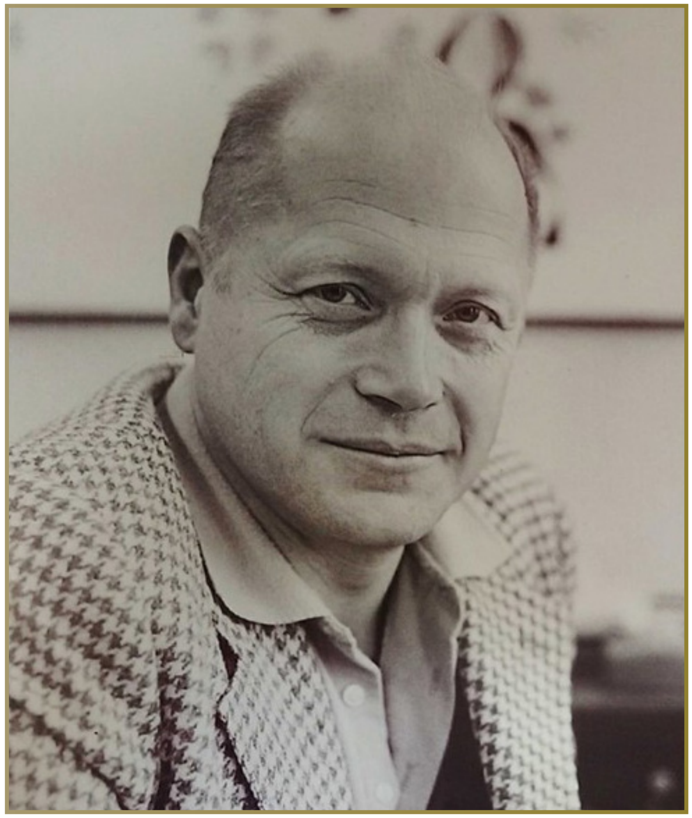

Figure 1 Norman Phillips, 1973. *Courtesy of MIT Museum.*

Early Life and Education

Norman Alton "Norm" Phillips was born on July 9, 1923, in Chicago, Illinois, to Alton Elmer Anton Phillips and Linnea (Larson) Phillips. All his grandparents were from Sweden. Norm's family name would have been Peterson, but his father changed it to Phillips.[1] Norm and younger sister Alice grew up in a hard-working and conservative Swedish American family in South Chicago. Many uncles, aunts, and cousins lived nearby, and the children had close relationships with them. Norm and Alice would often exchange overnight visits with their cousins. Alton Phillips was an accountant who lost his job at the beginning of the Great Depression, worked for a time as a traveling salesman despite his shyness, and eventually became the proprietor of a funeral business. He was a Mason. Sometimes Norm would help his father at the funeral home, but that profession never appealed to him. Both parents had only a high school education.

Norm got along well with his teachers and skipped from the fifth to the seventh grade. He took piano lessons throughout grade school and was introduced to the French horn when he started high school. The horn would become an intermittent but lifelong love and commitment. He also liked sports. As a youngster, Norm was an avid reader of the *Book of Knowledge* and the *Encyclopedia Brittanica* and was given a chemistry set by a neighbor boy and developed a strong interest in chemistry.[2] He had a paper route he delivered by bicycle and also had to extract monthly payments from customers. Throughout high school, he had both a morning and an evening route delivering the *Chicago Tribune* and the *Chicago Daily.* For entertainment, he and Alice listened to radio shows such as *The Lone Ranger*, *Little Orphan Annie,* and *Tarzan*. As he grew older, he enjoyed listening to classical music programs such as on the *Ford Sunday Evening Hour*. The show's theme song was the overture to *Hansel and Gretel* that included a French horn quartet.

Norm played the horn through high school and entered a competition in which he received a grade of "superior." He was elected vice-president of his senior class at Fenger Academy High School. In the summer of 1940, after graduating high school, he worked Saturday nights in a factory producing barium carbonate, which was used in the manufacture of bricks. His next job was unloading tomatoes at a cannery. He entered the University of Chicago in September 1940 to study chemistry and worked as a night clerk at the Union League Club of Chicago. He joined Kappa Sigma fraternity and successfully auditioned for the university orchestra.

That winter, the orchestra put on the operetta *The Armorer* by German composer Alfred Lortzing to celebrate the fiftieth anniversary of the University of Chicago. Because the university chorus was busy, the conductor sought members from the Swedish Choral Club of Chicago. Martha Nissen and her parents sang in that organization, and her parents volunteered to participate in *The Armorer*. Martha accompanied her parents to rehearsals, and when the conductor sought another soprano, Martha's father volunteered her from her place in the audience seats. Martha and Norman noticed one another but did not speak, and he did not know her name. Afterwards he looked in the program and found the only name that appeared three times. After searching the telephone books, he found her father, Emil Nissen, in the Berwyn suburban phone book. He was thus able to write to "that fascinating young woman." That was "the beginning of the most marvelous part of his life."[3]

As the United States prepared to enter World War II, Norm learned that the University of Chicago was involved in a military program to train weather forecasters. He enlisted in the U.S. Army Air Corps in January 1941. Thus began the second most important facet of his adult life: meteorology.

A Career in Meteorology

Norm switched to the meteorology program at the University of Chicago, which carried a promise that you would be sent to the Army meteorology training program when drafted. He first went to Keesler Field, in Biloxi, Mississippi, for basic training and then to the University of Michigan with about 500 other men for pre-meteorology, a heavy dose of mathematics, and physics. He was then shipped to Chanute Field near Rantoul, Illinois, for meteorological education. He became very interested in the subject and, for the first time in his life, began to study. He also was courting Martha at this time and took advantage of weekend passes to visit her in Chicago. His class finished in June 1944, about the time of D-Day, and he was commissioned as a second lieutenant.

Figure 2 Photo of Martha (Nissen) Phillips in early 1941. *Photo courtesy of the Norman A. Phillips Family Archive.*

After brief postings in McCook Army Air Field in Nebraska and Grenier Field in New Hampshire, he was stationed at Lajes Field on Terceira Island in the Portuguese Azores. From there, he forecast for C54s that flew to or from Bermuda, Newfoundland, England, Casablanca, and (later) Paris. He gained a lot of practical experience during this period. The forecasting was very challenging because observations were limited, and lives depended on accurate direction of flights that were subject to enemy attack as well as natural hazards such as strong headwinds, which might deplete the fuel before the planes reached their final destination.

One day, the local Portuguese official, Lt. Col. Agostinho, came into the office and warned that a hurricane was approaching, a rare event in the Azores. The team sent out their weather recon plane, which located the storm and verified its approaching path. All incoming planes were sent back to their departure base, and almost all planes on Lajes were sent to their destination. At that time there were no satellites to

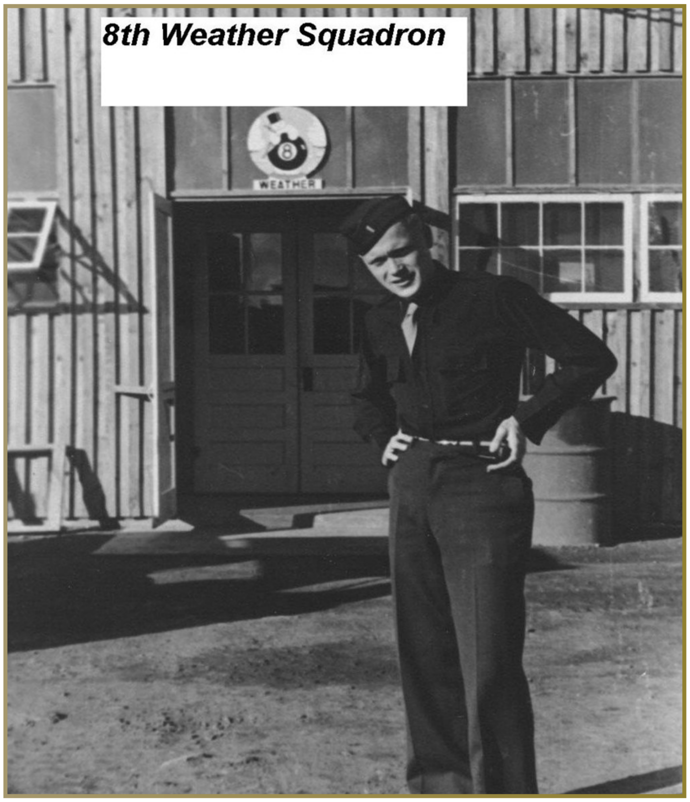

Figure 3 Norm in the Azores in 1944. *Photo courtesy of the Norman A. Phillips Family Archive.*

detect and monitor hurricanes, but Agostinho learned of the hurricane by observing the oceanic swell in the harbor. Norm joked that reading the swell in this way was not taught in meteorology school. Shortly after this, his team moved to Santa Maria Island, a smaller island southeast of Terceira.

During this time, Norm met Joseph Smagorinsky, who flew as an observer on weather reconnaissance flights. They were to become lifelong friends and colleagues. Norm made several reconnaissance flights in Joe's place and noted that fronts seem more like fronts when crossed at 150 miles per hour.

The German forces surrendered on May 8, 1945. As a more recent commission, Norm was not discharged but was given a three-week pass, which allowed him to travel home to Chicago and marry Martha on August 12, 1945. Their honeymoon overlapped with V-J Day. They remained happily married for sixty-six years until Martha's death on June 3, 2011.

Norm was discharged as a first lieutenant in August 1946 and then returned to the University of Chicago on the GI Bill to study meteorology. He had the idea that statistics would be important, and one of the first courses he took was from Tjalling C. Koopmans, who later received the Nobel Prize in Economics. Norm completed his bachelor of science degree in 1947 and continued for a graduate degree. Martha and Norman lived in a small apartment while he attended school, and their first two daughters, Janet and Ruth, were born in Chicago.

At that time, the University of Chicago had many leading meteorologists, including Carl-Gustaf Rossby and Victor P. Starr. It was a very stimulating intellectual atmosphere. The courses in dynamic meteorology were taught by Rossby, Starr, David Fultz, and George W. Platzman. Norm completed a master's thesis under Erik Palmén. Norm conceived the idea of following the subsidence of a mass of cold air, which he did by using a planimeter on the weather map. He tried to estimate the resulting transfer of energy between the cold air mass and the surrounding warmer air.[4] Norm received money as a student under the GI Bill and as an assistant editor to George Platzman for the *Journal of Meteorology* and also worked with classmate Hsiao-Lan Kuo under Rossby's Navy contract for which he wrote a report on sections across the jet stream that he had been drawing.[5]

Rossby convinced Jule Charney to stay most of a year in Chicago after Charney published his doctoral thesis at the University of California, Los Angeles (UCLA) explaining the baroclinic instability of the middle-latitude westerlies. Platzman had finished his doctoral thesis showing that a discontinuity in the jet stream could produce unstable motions, and fellow student Kuo had finished his classic work on barotropic instability.

Norm's Ph.D. thesis was written under the supervision of Platzman, who was only a few years his senior and with whom he developed a lifelong friendship. His work was done quite independently, however, because it was Rossby's policy that faculty should not suggest Ph.D. topics for students. Norm's thesis dealt with a stability analysis of a two-level model.[6] In it, he considered a simple system in which two layers of incompressible fluid with different densities were within a depth of fluid constrained between two immovable plates. He used the quasi-geostrophic scaling suggested by Charney to write approximate equations for the conservation of potential vorticity in each layer.[7] These were linearized, and stability criteria for the growth of unstable waves were derived. These criteria matched well the stability criteria derived by Eric Thomas Eady in his famous work using a continuous model.[8] Norm also tested the two-level model's ability to predict the time evolution of pressure and winds for observed cases of midlatitude wave development. Norm recalled, "This was the first-ever numerical forecast of sea-level pressure changes."[9] This work supported the idea that a two-level model would be a good first approximation for the dynamics and thermodynamics of the atmosphere, which led to Norm being the first to simulate the general circulation of the atmosphere.[10]

While a student of Platzman's, Norm had been a temporary member of Charney's group working to make weather forecasts

Figure 4 Norman Phillips at the IAS in Princeton. *Courtesy of the Institute for Advanced Study.*

with the ENIAC computer at the IAS in Princeton. Upon graduation, Platzman reminded Charney to invite Phillips to join the meteorology group there, and the family moved to the institute's housing compound in the late summer of 1951.

Institute for Advanced Study, 1951–56

Norm got a job straight out of graduate school with the meteorology group at the IAS and joined the team led by Jule Charney that was tasked with using the ENIAC computer to explore its use in weather forecasting.[11–14] A third daughter, Ellen, was born during this period.

When Norm and Martha arrived in Princeton, Charney and his wife, Elinor, and Joseph Smagorinsky and his wife, Margaret, were already there. Smagorinsky was employed by the United State Weather Bureau while working on a Ph.D. at New York University and had been sent to Princeton by Harry Wexler to become familiar with the methods of numerical weather prediction. Other visitors to the meteorology group at Princeton included Ragnar Fjørtoft from Norway, Kanzaburo Gambo from the University of Tokyo, George Platzman from the University of Chicago, and many others. The success of the early weather forecasts at Princeton led the Weather Bureau, Air Force, and Navy to form the Joint Numerical Weather Prediction Unit in 1954, under the leadership of George Cressman.

Phillips worked with Charney and others on simplifying the equations in an optimal way for weather prediction and formulating them for solution on the ENIAC computer. Charney and Phillips explored ways to extend the early work with a single-level model to models that could approximate the three-dimensional structure of the atmosphere.[15] They described experimental forecasts with 2- and 2.5-level models and discussed the extension to n-level models, which was not yet practicable given the limitations of the computing machines available at that time. They nonetheless emphasized the potential for improvements in forecasts when more powerful computers became available.

In 1953, Rossby asked Phillips to come to Stockholm, Sweden, to create a numerical forecast program for the Swedish Air Force. Swedish engineers had just about finished constructing the BESK computer, modeled after John von Neumann's design at Princeton. Norm helped them program a barotropic forecast and in 1954 they were able to make the first computer forecasts that were disseminated for public use. Prior to Sweden, Norm spent two months at Imperial College in London working with Eric Eady. Eady was doing experiments on a computer in Manchester and introduced Norm to computer pioneers Alan Turing at Manchester and Maurice V. Wilkes at Cambridge, as well as prominent meteorologists at Imperial College and Britain's Meteorological Office.

In Stockholm, Rossby provided tickets so that Norm and Martha could attend the Nobel Fest, which took place at the Stockholm Concert Hall and at Stockholm City Hall. When their time in Stockholm was done, they visited meteorologist Arnt Eliassen and his wife, Ellen, in Oslo. There, Norm computed the second-order effects from an unstable two-layer wave.[16] This work anticipated the indirect meridional circulation in middle latitudes that he would calculate with

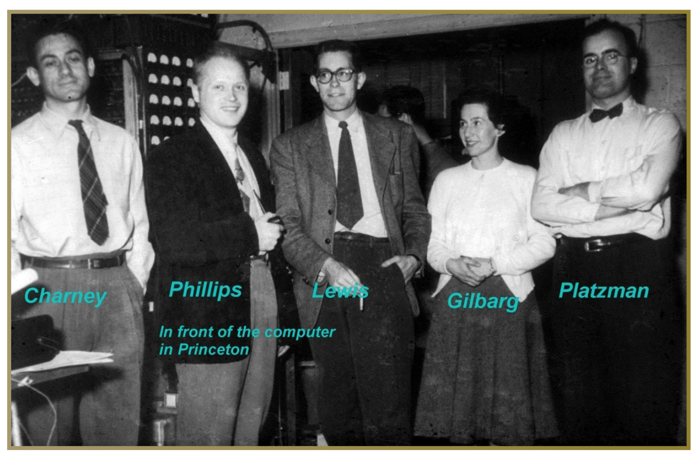

Figure 5 Some of the members of the Meteorology Project at the Institute for Advanced Study (IAS), L-R: Jule Charney, Norman Phillips, Glenn Lewis, Norma Gilbarg, George Platzman, the IAS computer is in the background; the photographer Joseph Smagorinsky was also a member of the project. *Courtesy of the American Institute of Physics.*

his fully three-dimensional model in his 1956 paper on the general circulation of the atmosphere.[17]

Back in Princeton, he began work on a three-dimensional model to simulate the effect of an unstable wave on the zonal wind. This seminal work on the general circulation of the atmosphere won Phillips the first Napier Shaw Memorial Prize of the Royal Meteorological Society of Britain (RMS). As it turned out, Phillips was able to attend the meeting of the RMS on June 20, 1956, and deliver his paper there. The impact of that work on scientists at that time can perhaps best be described by quoting from the minutes of the RMS meeting.[18]

> Dr. Phillips paper gives the results of a remarkable experiment in numerical calculation, the first of its kind to be attempted. The idea was to write down mathematical equations which describe the large-scale movements of the atmosphere; the description of the atmosphere is crude, but an attempt has been made to include the essentials, the effect of the earth's rotation, the heating and cooling by radiation and the frictional retardation. With these equations the courageous attempt was made to calculate what would happen if the atmosphere started from rest. If the resulting flow pattern were like the flow patterns observed, Dr. Phillips could really claim that he had explained the main features of the general circulation of the atmosphere.
>
> There was general agreement that Dr. Phillips had achieved his aim. His calculated charts showed the formation of a series of eastward progressing depressions in high latitudes and of anticyclones in lower latitudes. It shows the formation of the meandering upper westerlies with a tendency for a central jet, and several other features were suggestive of the daily weather map. This is not to say that Dr. Phillips's work has solved the problem of the general circulation – it is only a beginning, but it shows what can be done.
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> The discussion which followed seemed to aim to get at the lessons which could be drawn from this remarkable experiment in calculation, made possible by the modern electronic computer, and the speakers made the most of their good fortune in having the author over from Princeton, U.S.A. to pose him many friendly questions on the interpretation of his results. Clearly, they all wanted the experiment done many times more so that they could see the effects produced by this or that change in the basic hypotheses."

Phillips also showed that fronts were produced by developing baroclinic waves, which is opposite to the Norwegian theory that proposed waves grew as instabilities on preexisting fronts.

Von Neumann was impressed and convinced the U.S. government to establish a long-range predictions group in 1955, with Smagorinsky appointed to lead. It was initially based in Washington, D.C.; but was moved to the Forrestal Campus of Princeton University in 1967 and became the Geophysical Fluid Dynamics Laboratory. In 1956, von Neumann was negotiating with UCLA about taking a position there. Norm was flattered to later learn that part of the negotiation was that he and Charney would also be offered positions. But von Neumann was very ill with cancer by that time, and Charney and Phillips went to MIT instead. Von Neumann died in February the following year.

Rossby invited Norm to be the "first opponent" for Bert Bolin's thesis defense at Stockholm University in 1956, where Rossby had established the Department of Meteorology in 1947. It was a formal affair, and Norm was required to wear "frack" = "tails" for the presentation.

MIT, 1956-74

The family moved to Lexington, Massachusetts, in 1956 when Norm joined the faculty of MIT. His first discovery there was a simple way to allow for orography in atmospheric models, the so-called sigma coordinate system.[19] This method has been used in many global atmosphere models for weather prediction and climate simulation.

In a 1959 paper, Phillips showed that simple models could become unstable because Fourier components could be misinterpreted.[20] Wavenumbers above the maximum that can be represented are produced by non-linear interactions and would be reflected into wavenumbers of low order. In a second paper published in 1959 and another in 1960, Norm advanced the theory and practice of using the primitive equations for numerical weather forecasting and their advantages over the quasi-geostrophic equations.[21,22] He showed that to avoid "noise" in the forecast, the initial divergence must be computed from the geostrophic system, and that the wind and geopotential should be related by the "balance equation." He also dabbled productively in physical oceanography[23,24] and laboratory studies of rotating fluid dynamics.[25]

Norm next began developing a strategy for combining coarse and fine grid meshes in weather forecasting,[26] as well as techniques for models that combined atmospheric dynamics with atmospheric chemistry.[27]

Teaching and Mentoring

Norm was an excellent teacher and mentor in the Department of Meteorology at MIT. He mentored many highly successful Ph.D. students but declined to be listed as a coauthor on the published papers of his students, a tradition he carried on from his own experience at the University of Chicago.

He was nonetheless an engaged, generous, and supportive mentor. He liked to derive equations with his students while smoking his pipe in his office.

Norm was an exceptionally rigorous and thoughtful educator, renowned for his detailed lectures and challenging assignments that emphasized precision. His teaching style, marked by clarity and elegance, left a lasting impact on students, who valued his patience, thoroughness, and ability to distill complex concepts like quasi-geostrophic theory and anelastic equations into manageable lessons. Despite his demanding standards, he was approachable, often recognizing his own rare mistakes and generously supporting students' efforts, thereby fostering a deep respect. He was very kind to students and was both feared and loved by them.

Beyond the classroom, Phillips was known for his kindness, humility, and engagement with students and colleagues. He balanced academic rigor with personal warmth, whether through encouraging an expectant female student, playing touch football, or surprising seminar speakers with incisive questions after appearing disengaged. His competitive spirit in sports—when he played football or volleyball, he played to win—and passion for music revealed a multifaceted personality. Colleagues and students alike admired his intelligence, ethical character, and mentorship.

National Meteorological Center, 1974-88

Norm served as head of the Department of Meteorology at MIT from 1970 to 1974, when he left to join the National Meteorological Center in Washington, DC, as principal scientist. Several reasons have been suggested for why Norm made this move. As department head, he was giving his best ideas to his grad students, and they were "having all the fun." He wanted to spend more time doing research himself.[28] He said that his goal in giving up a prestigious professorial appointment to work for the government came from a sense of wanting to help the National Weather Service make better forecasts by bringing in the latest ideas and technical tools.

His main goal in his new role was to improve the operational forecasting system. In particular, he helped develop the Nested Grid Model, which combined a global analysis system with an embedded model with much higher spatial resolution.[29] In addition, he learned about remote sensing and worked to effectively incorporate measurements from satellites into the global analyses of initial conditions for weather forecasts. He pointed out the effects of rain on microwave temperature measurements and devised ways to prevent such effects from harming the forecast.[30,31,32] He did fundamental work on the modes of atmospheric motion and their roles in long-range weather forecasting.[33,34]

Post-Retirement Research

Norm retired from the National Weather Service in 1988, beginning a long retirement of thirty-one years. He and Martha moved to Merrimack, New Hampshire, to be near their children. During his retirement he continued to publish scientific works, as well as essays on the history of meteorology and, in particular, on the history of numerical weather prediction. His historical essays include remembrances of Rossby,[35] quasi-geostrophic theory,[36] and Sverre Petterssen.[37] Scientific topics included the Coriolis effect[38] and the Foucault pendulum.[39,40] He was a speaker at many symposia celebrating numerical weather prediction and the scientists who developed it. In 2000, he was invited to a symposium in Potsdam, Germany, to celebrate the fiftieth anniversary of the first numerical prediction on the ENIAC.[41] In 2003, Norm and Joe Smagorinsky were jointly honored with the Benjamin Franklin Medal in Earth Science by the Franklin Institute. Norm also attended an American Meteorological Society symposium in his honor in Seattle in 2004. At the age of ninety-one, he published what would be his last scientific paper, a discussion of inertial motion on a rotating sphere.[42]

Honors

Norm received many accolades and honors over his long career, including the inaugural Napier Shaw Prize from the Royal Meteorological Society (1956), the Clarence Leroy Meisinger Award (1960) and the Award for Outstanding Contribution to the Advance of Applied Meteorology (1989) from the American Meteorological Society, the Editor's Award from the American Meteorological Society (1969), the Administrator's Award from National Oceanographic and Atmospheric Administration (1981), and the Professional Achievement Award from the Alumni Association of the University of Chicago (2004). He also was awarded the Carl-Gustaf Rossby Medal of the American Meteorological Society (1971), the Department of Commerce Gold Medal (1988), and, with Joseph Smagorinsky, the Benjamin Franklin Medal in Earth Science from the Franklin Institute, 2003. He was a member of the American Academy of Arts and Sciences and the National Academy of Sciences and an honorary member of the Royal Meteorological Society and the American Meteorological Society. In 1982, he was named that year's Distinguished Lecturer by the American Meteorological Society and in 1987 was named the featured lecturer at the Sixth World Meteorological Organization Conference.

Family Life

Norm was a devoted husband and parent who instilled a sense of wonder and problem-solving in his children, as seen when he proudly guided his young daughter to understand why bubbles are round and how to estimate the height of their house. His commitment to family extended to activities like skiing on a nearby golf course and participating in lighthearted family horse shows in Maine, where his resilience shone through as he repeatedly remounted after being thrown off. He made life fun. As a gentle and patient husband, Phillips exemplified love and respect in his marriage, calmly addressing his wife Martha's health frustrations with kindness and setting a powerful example of tenderness for his children's own relationships. Whether sharing bacon-and-egg breakfasts atop Flagstaff Mountain or navigating life's challenges, Norm showed love, perseverance, and abiding connection with family and many lifelong friends.

Acknowledgments

This remembrance relies heavily on published interviews with Norman Phillips and on documents that he himself prepared and provided on DVD to Mankin Mak, one of his graduate students. In many places here we have chosen to use his own language in describing events, and in some cases we have added quotation marks to the text to indicate this. We also received personal remembrances collected by his youngest daughter, Ellen Chasse, and many of his former students and colleagues. Because so much time has passed since he left MIT in 1974 and NMC in 1988, we could not find a complete bibliography and had to do our best to construct one from library searches and from documents Norm provided in his DVD.

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