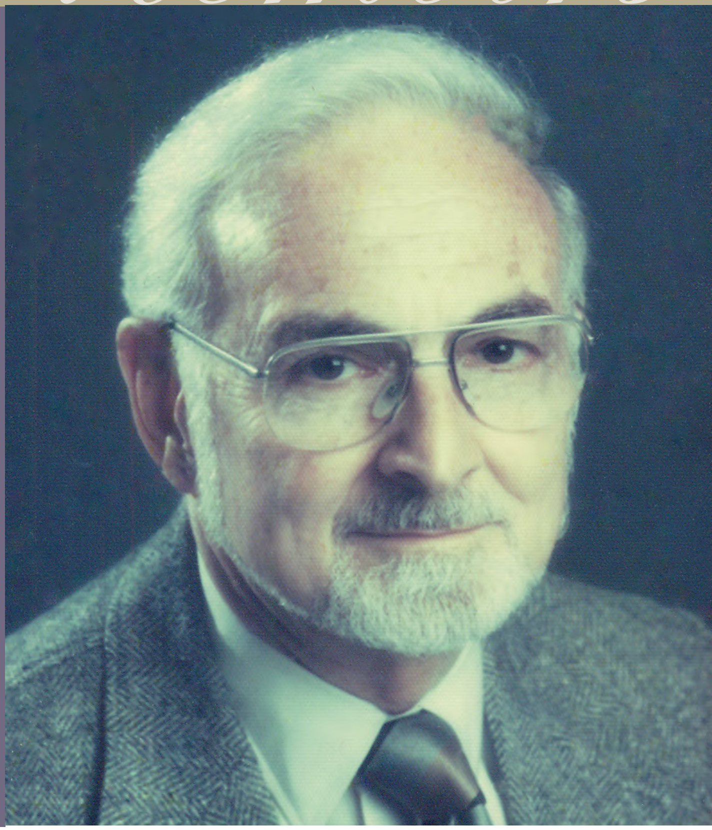
Richard J. Reed

1922–2008

BIOGRAPHICAL *Memoirs*



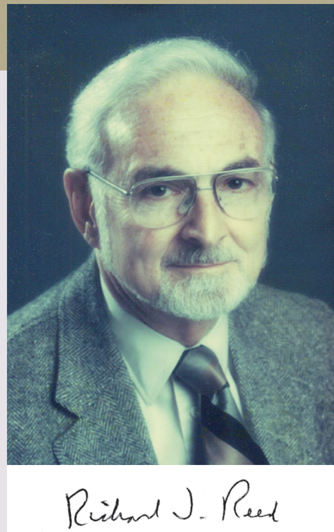
A Biographical Memoir by
John M. Wallace

NATIONAL ACADEMY OF SCIENCES

RICHARD JOHN **REED**

June 18, 1922–February 4, 2008

Elected to the NAS, 1978



By John M. Wallace

Richard John Reed, known to his friends as Dick Reed, was trained as a synoptic meteorologist of the "old school." He derived aesthetic enjoyment from depicting weather patterns and was exhilarated by the competitive aspect of weather prediction. He practiced weather forecasting when it was still an art and he was good at it. Upon learning of Reed's death, his long time friend, Richard Goody remarked, "There is a sense in which Dick's passing marks the end of an era in American meteorology." Reed also helped to usher in a new era: he was among the leaders in the late-20th-century revolution that transformed weather forecasting from an art into a science.

Along the way, Reed surveyed, contemplated, and wrote about the wonders of the atmosphere: the long range transport of stratospheric ozone; a remarkable quasi-biennial periodicity in stratospheric winds; sudden warmings of the stratospheric polar cap region; atmospheric tides; clear air turbulence; tropical waves and their embedded deep cumulus convection; severe local wind storms; cyclones over the polar regions; rapidly deepening extratropical cyclones; and bogus sightings of flying saucers. Reflecting back on his diverse array of research interests many years later, Reed reflected, "I was like a kid in a candy shop." Colleagues and former students fondly recall his high energy level, his boundless curiosity, and his expressive and contagious enthusiasm.

Boyhood

Richard John Reed was born in Braintree, Massachusetts, birthplace of John Adams, John Quincy Adams and John Hancock. He was the second of three sons born to William A. and Gertrude (née Volk) Reed. William was an attorney whose practice was mainly focused on the needs of middle-class families. He was described as kind and creative and as having a good sense of humor.

Reed's childhood was relatively unstructured. Most days he and his brothers were free to roam after school. Reed later remarked that his parents never read him a story, nor did they take much interest in his academics until quite late in his life. He didn't think this reflected poorly on them; it was just the prevailing way of life at that time.

Reed described himself as an "average student" when he was in elementary school. Upon reaching high school his grades improved and he and several of his classmates were allowed to take advanced placement classes at the local college. Although he was only 5' 7" tall and relatively light in weight, Reed played on his high school football team and ran track, for which he earned (and saved) many engraved trophies. He was well liked in high school and became valedictorian of his graduating class.

1941–1946: In the Navy

At the time he graduated from Braintree High School in 1940, Reed described himself as having "well-rounded abilities and no strong leaning toward any particular subject or career choice," though he allowed as how he had been keeping a diary of weather observations as a hobby while he was in high school. He would have liked to go to MIT or Harvard but could not afford the cost of tuition, even with the scholarship that he received upon leaving high school. So Reed chose the seemingly most practical option available—to enroll at Boston College and major in accounting, a field in which he could at least work with numbers and would have a reasonably good prospect of finding a job as a certified public accountant upon graduating. When his scholarship ran out at the end of his freshman year he went to work in a shoe factory, hoping he would be able to earn enough money there to enable him to return to college the following year.

That December, the Japanese bombed Pearl Harbor and war was declared. Reed put his college plans on hold and immediately enlisted in the Navy as an apprentice seaman. He reported for duty in Newport, Rhode Island just a few weeks later. Of the specialties offered to new recruits, he chose three possibilities, including aerology (the Navy's term at that time for meteorology), and that was the program that he was assigned to. He was placed in an on-the-job training program at Quonset Point Naval Base, where his most memoroable instructor was Albert Lewis, a man whom he described, as "a colorful character from Arkansas with a limited academic background but high native intelligence." Reed had a great respect for Lewis's ability as an analyst and a forecaster, and he credited Lewis with helping him to acquire those skills by direct instruction and by example. "Lewis's map analyses were a thing of beauty that had a profound effect on my aesthetic appreciation of meteorology, Reed recalled. "The emotional charge that I have always felt in analyzing frontal cyclones stemmed from his early example."

After they had completed their own training, Reed and two of his cohorts were assigned to instruct the new trainees in the elements of meteorology. Reed was so intrigued with the recommended textbook (Blair 1937) that he stayed up all night reading it. His enjoyment was compounded by his discovery that he was capable of mastering the material despite his limited scientific background. Reflecting back on the experience, he later wrote:

> *There are those who view unusual ability in physics as the key to scientific success and its manifestation in a particular subject as largely a matter of accident. I have never subscribed to this view. The aesthetic feelings aroused in me by weather patterns and the fascination I felt for weather phenomena as physically evolving entities have always seemed to me inborn facets of my being. I cannot picture any other field of study having had the same emotional effect.*

For a while, it appeared that Reed would qualify for a fleet appointment at the US Naval Academy, but he failed the vision test because of mild astigmatism. As a "consolation prize," as he put it, he was assigned to Dartmouth College for a year of course work in the standard academic subjects. Before his year at Dartmouth was over, Reed applied for and was selected for a year of training in the Meteorology Program at Cal Tech in the Aeronautical Engineering Department, directed by the flamboyant Irving P. Krick, about whom Reed had heard stories since his earliest days in the Navy.[1] As it turned out, Krick was on assignment in Europe that year as a colonel in the Air Force, and Reed never encountered him. Reed was satisfied with the training that he received from the staff in Krick's program, and he felt privileged to have taken his more advanced courses from eminent faculty members Beno Gutenberg and Homer Joe Stewart, and to have been in the same department as Theodore Von Karman. By the time he completed his year at Cal Tech in June 1945, he had accumulated enough credits to qualify for a Bachelor of Science degree. He was discharged from military service a year later.

1946–1954: At MIT

Reed enrolled in the graduate program in MIT's Department of Meteorology at in September 1946, three months after his discharge from the Navy. By that time, Henry Houghton had taken over from Sverre Pettersen as department chairman, and Victor Starr, Bernhard Haurwitz, James Austin, and Hurd Willett were serving on the faculty.

Reed's doctoral dissertation, under the nominal supervision of Hurd Willett, was entitled, "The Effect of Atmospheric Motions on the Distribution and Variation of Ozone." By that time Willett's research interests were becoming increasingly focused on the role of the sunspot cycle in forcing variations in the atmospheric circulation, perhaps by modulating the rate of production of stratospheric ozone. In contrast, Reed's research was limited to the relationship between the ozone distribution and weather, and the inferred causality was in the opposite direction: i.e., on the role of time-varying weather patterns in driving variations in total ozone. Reed completed his thesis, received his ScD in June 1949 and published a paper based on his thesis in the *Journal of Meteorology* the following year. Reed's research showed how, in the presence of an upward and poleward-directed climatological-mean ozone gradient, subsidence and equatorward flow in the vicinity of the tropopause can increase local ozone concentrations by advection and vice versa. This simple mechanism explained the relationship that had previously been reported between column-integrated ozone and upper-air flow patterns, with elevated ozone concentrations in the troughs of the upper level waves.

After completing his doctorate, Reed stayed on at MIT for another five years as a research associate, supported by one of Austin's research grants. This position offered him considerable freedom to explore new research interests. Along the way he came into contact with Frederick Sanders, who was a graduate student in the department at that time. Reed and Sanders both questioned one of the basic tenets of the model of cyclone development advocated by the so-called "Norwegian school": the notion that cyclones develop along strong preexisting thermal discontinuities, which extend with nearly equal strength through the depth of the troposphere.

Reed and Sanders were aware that frontogenesis (i.e., the intensification of zones of strong thermal contrast) often proceeds in synchrony with cyclogenesis (i.e., the deepening of cyclones) rather than in advance of it, They also knew that frontal zones tend to be much stronger in the lower troposphere just above the ground, and/or near the tropopause than they are in the mid-troposphere. To illustrate the relationship between cyclogesesis and for formation of fronts they carried out a case study documenting the development of a mid-tropospheric frontal zone in response to the overturning circulation in the plane normal to the orientation of the isotherms. At the suggestion of Victor Starr, they made extensive use of Ertel potential vorticity as a dynamical tracer. Reed also acknowledged Starr's role in "encouraging skepticism with regard to accepted ideas, the necessary attitude for the young scientist intent on breaking fresh ground."

Reed and Sanders became good personal friends and remained so throughout their lives. But both of them were highly competitive, especially when it came to weather forecasting.

Reed and Sanders became close friends and remained so throughout their lives. But both of them were highly competitive, especially when it came to weather forecasting.[2] One day, Sanders invited Reed to go sailing with him on his boat in Marblehead, a seaside town north of Boston. Sanders drove to within walking distance of the dock where his boat was moored and parked his convertible on the street, leaving the top down. Noting that it was a hot and muggy day, Reed suggested that it might be a good idea to put the top up because of the risk of afternoon thundershowers. But Sanders, assuring him that there was nothing to worry about, left the top down. Whereupon, Reed bet him a case of beer that it would rain before they returned to the car. By Reed's account, a thunderstorm did, in fact, develop while they were out sailing and they got drenched. But when they walked back to Sanders' car they discovered that the edge of the rain was down the middle of the street on which Sanders had parked, and his car was completely dry. Nevertheless, Reed claimed to have won the bet, and he recalled Sanders presenting him with a case of beer at their next social occasion.

The last major paper that Reed wrote at MIT—the most highly cited of his early works—was a case study of upper-level frontogenesis. Based on an analysis of the evolving distribution of potential vorticity on isentropic surfaces, he traced the development of a sloping frontal zone (a stable layer marked by strong vertical wind shear and an upward decrease in relative humidity). He showed in this paper that the frontal zone consisted of a thin wedge of stratospheric air that had descended to the 850-hPa level; that the associated frontal boundaries were a folded portion of the original tropopause; that the overturning circulation within the frontal zone was thermally direct, with adiabatic compression within the polar air mass giving rise to temperatures as high as those observed in tropical air masses; and that frontogenesis is not a precursor of cyclogenesis, but a part and parcel of it.

While at MIT, Reed met and married Joan Murray, an English emigrée. Joan's mother, Elizabeth (Elsie), had been widowed at the beginning of the World War II, and Joan, the elder of her two daughters, spent part of her youth (ages 9–13) evacuated to an orphanage in Wales. At the end of the war Joan rejoined her family in Newcastle. Like many other young English women at that time, she ended her schooling early and went to work to help support her family. In 1947, Elsie decided to move with her daughters to Boston, where she had a few friends, to start a new life. Having acquired some work experience in the insurance business, doing “men’s work” during the war, she was hopeful that she would be able to find work. Luckily, on her first day of job-hunting in Boston, she was hired by an insurance agency. Reed and Joan met at a church-sponsored outing and began dating. He was able to secure a position for her in the map room at MIT. Within a year they were married, their son Ralph, named after Joan’s father, was born two years later.

Ralph’s birth was announced “on air” by the pseudonymous “Don Dixon”, which was the name that Reed used when he delivered his daily weather forecasts for a local radio station. These forecasts were transmitted to the station by telephone from his and Joan’s tiny saltbox in Braintree. Few, if any of Reed’s colleagues were aware of his former life as “Don Dixon”, but Joan recalled, many years later, how difficult it was to keep Ralph and his infant brother, Richie, quiet during their father’s broadcasts.

1954–1964: Early years at the University of Washington

While Reed was working as a postdoctoral research associate at MIT he received several informal academic offers from what he considered to be reputable meteorology departments, but on the advice of Henry Houghton he elected not to pursue them. Hence, he was surprised when Houghton encouraged him to seriously consider a job offer that he received in 1954 from the University of Washington (UW), which he described as “a little known player in the meteorological firmament.” Robert Fleagle tells the story of Reed’s recruitment from the UW perspective:

> *In 1954 approval was obtained for a national search for a synoptic meteorologist. At that time, the usual first step was to request recommendations from the leading people in the field, ‘the old boy network.’ That procedure led to a suggestion by James Austin of MIT that we consider Richard (Dick) Reed, a member of their research faculty, who had gotten his doctorate in 1949. I visited Dick in Cambridge on a trip east and was especially impressed by the breadth of his research interests, which embraced stratospheric ozone as well as tropospheric weather analysis and forecasting. We invited him to visit UW, at that time, an unusual step*

> *in the recruiting process. The visit went well, and Dick was offered and accepted an appointment as assistant professor, bringing the faculty to five tenured and tenure-track faculty members.*

Reed's first encounter with Seattle cannot be described as "love at first sight." He and Joan and their two sons had endured a grueling motor trip across the country, crammed into their Nash. Joan was in the early stages of pregnancy with their daughter, Lisa and suffering from bouts of morning sickness. As they descended from the crest of the Cascades, they were eager for their first sight of what department chair, Phil Church, had promised would be a glorious city, surrounded by snow capped mountains, and resplendent in the autumn sunlight.

But the vision faded as they descended though a deck of low clouds that remained so stubbornly anchored in place throughout most of their first winter in Seattle that Joan was beginning to wonder whether the mountains really existed. The Reed family endured the gloomy winter while living in married student housing built over what had previously been a "landfill" (dump) on the University of Washington campus. Meanwhile, Reed had heavy teaching responsibilities. He hadn't fully realized when he took the job that he would be teaching the department's large undergraduate classes in synoptic meteorology, which had previously been taught by two instructors, or that the courses included time-consuming laboratory sections that took up much of his afternoons.

Reed's first graduate student at UW was Edwin Danielsen, a highly talented synoptic meteorologist, whom Reed regarded as more of a self-directed peer than a student whom he mentored. Danielsen shared Reed's deep appreciation for the aesthetic dimension of meteorological analysis and, like Reed and Sanders, he resisted the orthodoxy of the "Norwegian School." In 1959 Reed and Danielsen published a co-authored paper in which they concluded that upper-level fronts can form as a result of "tropopause-folding", a mechanism that entrains large volumes of stratospheric air into the troposphere and brings it down to the Earth's surface along sloping trajectories within frontal zones.

Stratospheric air at that time was serving as a reservoir for strontium-90 and other radioactive isotopes released into the upper atmosphere by U.S. and Soviet nuclear-weapons tests. Alarmingly high concentrations of these radionuclides were turning up in cows' milk in Canada and in other countries far removed from the nuclear test sites and this was occurring a year or more after the tests had been conducted (much longer than the time required for solid particles to be washed out of the troposphere by being entrained into cloud droplets). Tropopause folding proved to be the culprit. Brian Hoskins (2003) credited the paper of Reed and Danielsen, along with Reed's two prior papers cited above, as having been influential in laying the groundwork for a theoretical understanding of baroclinic waves and their associated frontal structure. Hoskins noted, in particular, Reed and Danielsen's "striking use of the advanced theoretical concept of the conservation of potential vorticity."

During that period, one of the principal research missions of the UW Meteorology and Climatology Department was to advance our understanding of the climate of the Arctic. In support of this effort, Reed carried out an Air Force-sponsored project on weather analysis and forecasting in the Arctic. One peer-reviewed publication resulted from this work: a survey of the Arctic summer upper air climatology, the first of its kind. Reed also prepared a training manual entitled *Arctic Forecast Guide* while working as a consultant to the Navy.

Reed's early years at UW coincided with the advent of numerical weather prediction (NWP) based on the Navier-Stokes equations, simplified in accordance with scaling considerations elucidated by works of Jule Charney, Norman Phillips, and others. Barotropic (one layer) models came into widespread use in the late 1950s, but the implementation of baroclinic (two and multi-layer) models did not occur until some 10 years later. Although it was not his primary interest, Reed played a role in the implementation of the first baroclinic models at the National Meteorological Center (NMC). Sensing the advent of the digital era but not being conversant with computer programming himself, he developed a set of graphical procedures that could be used for solving a two-layer version of the quasi-geostrophic equations. His protocol incorporated a simple numerical relaxation scheme for solving Poisson's equation to recover the geopotential height tendency from the potential vorticity tendency. Reed intended that his method would be used mainly as a teaching tool in synoptic lab courses, but staff at the National Meteorological Center (NMC) found it sufficiently useful that they had it coded in machine language while Reed was visiting during his first sabbatical year (1962–1963) and it was used operationally for a few years in parallel with semi-empirical graphical schemes. In this sense, the "Reed prog" —as it was called—was a forerunner of the first operational, multi-level numerical weather prediction schemes.[3]

Up to the late 1950s, the time-varying circulation of the tropical stratosphere was still virtually unexplored. In the absence of repeated measurements, the prevailing view was that the circulation there was steady. A belt of easterlies, centered on the equator and encircling the globe was envisioned as prevailing in the 25–30 km layer, where a layer of sulfate aerosol injected by the eruption of Mt. Krakatoa in 1883 had been optically tracked, based on ground-based measurements, as it drifted westward around the globe. The eastward tracks of balloons released in an African expedition by the German meteorologist Arthur Von Berson in 1908-1909 were suggestive of a layer of westerlies in the lower stratosphere. The "Krakatoa easterlies" and von Berson westerlies" were regarded as permanent fixtures of the stratospheric circulation.

Monitoring of the time-dependent stratospheric circulation began during Reed's early years at UW. By 1953, the radiosonde balloons that were being released twice a day from tropical stations in support of operational weather prediction and U.S. nuclear weapons testing were regularly penetrating up to the 30 km level. Winds and temperatures at each station for an array of pressure levels were summarized in the form of monthly reports by the Air Force, in cooperation with the Weather Bureau, and sent to interested parties—including Reed. He and his colleague, Joost Businger, were present in September 1959, when Col. Frank McCreary, one of the military personnel at Christmas Island, presented a paper at an American Meteorological Society (AMS)-sponsored meeting in Minneapolis, describing time variations in tropical stratospheric winds observed over the course of two years. The data showed an apparent downward propagation of successive easterly and westerly wind regimes.

After perusing a summary of McCreary's presentation two months later in response to a suggestion by Businger, Reed concluded that the steady state paradigm for the tropical stratospheric circulation was no longer tenable and he began perusing the reports with tropical wind data that had been accumulating on the bookshelves in his office with hopes that they might hold the answer to what would take its place. "I feverishly pulled these [reports] from the shelves and roughly tabulated the stratospheric wind data for nine stations in the equatorial Pacific." He later wrote:

> *It turned out that at one of the stations, Canton Island, there were enough high-reaching soundings to establish that the pattern of downward propagating easterly and westerly winds occurred for at least two cycles and that all stations in the sample shared the pattern. Intuitively (or wishfully) I assumed that the cycle was a regular feature of the equatorial stratosphere and so reported it at the AMS annual meeting in Boston in January 1960.*

Reed waited almost another year—until he had confirmed the existence of the wind variations based on data from a station at Nairobi, Kenya—before he submitted a paper documenting these wind variations to a peer-reviewed journal.

Reed's discovery of what has come to be called the "quasi-biennial oscillation (QBO)" was, by his own account, one of the highlights of his career and his most original work. Of all the non-orbitally-related "oscillations" and "cycles" that have been identified in atmospheric data, the QBO exhibits by far the narrowest and most clearly defined spectral peak. It is the only phenomenon on Earth that is as periodic as the 11-year sunspot cycle.

But with the benefit of hindsight, it is fair to say that had Reed not discovered the QBO, someone else would have done so very soon thereafter. Indeed, in March,1961, the very same month that Reed's paper reporting his discovery appeared in the *Journal of Geophysical Research*, Veryard and Ebdon reported similar findings in the British journal, *Weather*. However, it is notable that in the years that followed, it was Reed who did the definitive work in documenting the meridional structure of the QBO, identifying its temperature signature and showing that the QBO-related zonal wind and temperature signatures are in thermal wind balance, even very close to the equator. It was Reed's National Science Foundation (NSF)-funded research grant that supported the work of James Holton and Richard Lindzen, that led to what has become the widely accepted theoretical interpretation of the QBO.

Concurrently with his QBO research during the early 1960s, Reed supervised his second Ph.D. student, Carl Kreitzberg, who analyzed five winter and spring storms passing over the Pacific Northwest during 1961, making use of vertically pointing weather radar together with serial balloon ascents. The doctoral theses of Reed's third and fourth students, John Perry and Stuart Muench, focused on the extratropical stratospheric circulation and—in particular, on the diagnosis of another newly discovered phenomenon: episodic sudden warmings of the wintertime polar stratosphere, accompanied by breakdowns of the westerly "polar night jet" that encircles it.

In contrast to Reed's research, which was on the cutting edge of synoptic meteorology as it was practiced at the time, Perry's and Muench's studies involved quantitative, computer-intensive general circulation diagnostics. Their research contributed to building a conceptual framework for understanding the sudden warming phenomenon in which vertically propagating, amplifying, planetary-scale Rossby waves, forced from below, produce bursts of enhanced poleward heat fluxes that warm the polar-cap region at rates on the order of 10°C per day. The eddy-induced warming of the polar-cap region drives a strong, thermally indirect mean meridional circulation with polar upwelling and equatorward flow at the level of the polar night jet. The westward Coriolis torque on this air as it flows outward from the Earth's axis destroys the jet in a matter of just a few days.

Another of Reed's forays into the upper atmosphere involved the analysis of newly available rocketsonde data from the White Sands Missile Range in New Mexico and other sites, consisting of vertical profiles of wind and temperature extending up to levels as high as 65 km. These soundings were widely separated in space and time and they were not very numerous, but Reed recognized that they were well suited to documenting the three dimensional structure of the diurnal and semidiurnal atmospheric tides. Reed's fifth Ph.D. student, Donald McKenzie carried out much of this analysis. While this work was in progress, Reed invited Richard Lindzen to visit for a year (1964–1965) as a postdoc. Reed's analysis of the rocketsonde observations proved to be a key piece of evidence in validating Lindzen's theory of atmospheric tides.[4] The observational findings of Reed and McKenzie were published in five short, relatively straightforward papers with publication dates between 1965 and 1969.

Two of Reed's graduate students during the mid-1960s wrote MS theses on the topic of supercell thunderstorms. The first of these by George Hammond (1966)—published as an ESSA Technical Memo the following year—was a case study of a severe thunderstorm that propagated toward the left relative to the steering flow, in contrast to the more typical "right moving storms." The peculiar behavior of this storm was regarded largely as a curiosity at the time, but a decade later Joseph Klemp and Robert Wilhelmson (1978) showed, on the basis of numerical simulations, that supercell thunderstorms are formed by the splitting of a parent storm, yielding a right-moving storm with cyclonic rotation and a left-moving storm with anticyclonic rotation. Most severe thunderstorms develop in regions where the wind veers with height, which favors the development of the much more common right-moving storms. Hammond's technical report proved to be instrumental in verifying this important conceptual breakthrough in thunderstorm dynamics.

As the graduate and undergraduate degree programs at UW grew during the late 1950s and early '60s, Reed, being the only synoptic meteorologist on the faculty, was called upon to teach larger classes. The range of topics that he felt that he needed to cover in his classes also expanded because he was convinced that students should learn how to use objective analysis techniques such as regression analysis, harmonic analysis, and power spectrum analysis, and that they should understand the logical underpinnings of risk

Reed (right) pictured with departmental colleagues, Conway Leovy (left) and James Holton (center), while stopping for lunch on a hike in the North Cascades in summer 1975.
(Photo courtesy Richard Johnson.)

assessment. To support his teaching of this material he used the textbook written by Hans Panofsky and Glenn Brier, and he also compiled his own set of handwritten lecture notes that contained both basic derivations and practical applications.

Reed's notes, which I later adapted for my own teaching served as my introduction to objective analysis. Among the memorable lessons that Reed taught me were (1) that one should be wary of empirical relationships that become apparent only through the use of sophisticated and/or intricate statistical analysis protocols, and (2) that there is no point in using sophisticated methods of statistical analysis if the same result can be obtained using simpler methods (i.e., one shouldn't use a sledgehammer to swat a fly).

Reed served as an Associate Editor of the *Journal of Meteorology* from 1957 to 1965, during which time its name was changed to the *Journal of Atmospheric Sciences*. From 1966 to 1968 he served as the Chief Editor for the *Journal of Applied Meteorology*.

Reed was as dedicated to maintaining his physical fitness as he was to his professional work. At lunchtimes he regularly pursued his daily regimen of running and stair climbing in the UW Husky Stadium and he managed to recruit new faculty hires, notably Peter Hobbs, James Holton, and me (for a year or so) to join him. He learned how to ski well enough to enjoy technically challenging, thinly populated runs, of which his favorite was "Seventh Heaven" at Stevens Pass in the North Cascades. And he experienced some of the basic training that he missed out on when he was in the Navy when he enrolled in a winter mountaineering class with his son, Richie. Reed recounted how Richie and others hurled him down a steep snow slope on his back, head first, again and again so that he could practice making self arrests by plunging his ice axe into the snow. During the brief, snow-free summers, he enjoyed hiking at a brisk pace in the Cascades.

Despite his less than triumphal entry into the Pacific Northwest, by the end of his first decade at UW, Reed had become as strong a booster for the collegial atmosphere of the department and for the pleasures of living in the Pacific Northwest as department founder (and at that time still chairman), Phil Church. To anyone who would listen, he would tout Seattle's mild year-round climate, the views of distant mountains, the absence (at that time) of heavy automobile traffic, and the availability of fresh berries and wild salmon. Through his efforts, a spectacular photo of lenticular clouds over Mt. Rainier was published on the cover page of the July 1965 issue of the *Bulletin of the AMS*.[5]

Reed's penchant for orderly planning in his research and teaching carried over to family events. His children recall that he often planned and mapped their travel itineraries down to the minute, keeping track of mileage and gasoline consumption. His frustration with the unpredictable nature of travel was only surpassed by his joy and wonderment at the many parts of the world that he and his family experienced together. For example, they spent several idyllic summers at a cottage overlooking Sheep's Pond on Cape Cod. Reed preferred body surfing in the ocean to swimming in a pond, but the pond was safer for the children. He was a strong, self-taught swimmer who wanted to be timed as he swam back and forth across the pond, trying to break his previous record.

1965–1975: Expanding horizons

Throughout most of his first decade at UW, Reed was a junior faculty member in a small department, with heavy responsibilities for undergraduate teaching and supervision of MS students. During his second decade, the department expanded with the hires of Peter Hobbs (1963), James Holton (1965), the author (1966), Conway Leovy (1968), Robert Houze (1972), and Peter Webster (1973), and Reed assumed the role of a senior faculty member.

For his second sabbatical (1968–1969), Reed accepted an invitation to serve as Executive Scientist for the U.S. Committee for the Global Atmospheric Research Programme (GARP), assisting the committee chair, Jule Charney and co-chairs Verner Suomi and Joseph Smagorinsky.[6] Reed had lead responsibility for orchestrating the early planning that led to the GARP Atlantic Tropical Experiment (GATE) in 1974 and the Global Weather Experiment (GWE) in 1979–1980. These so-called "GARP experiments" demonstrated that the atmospheric sciences community was capable of setting goals, conducting strategic planning, and executing programs collaboratively and successfully in a complex international political environment. They led to important advances in the state-of the-art of numerical weather prediction, and they heightened the level of international cooperation in atmospheric science long before the thawing of the Cold War. Many scientists contributed to making the GARP a success, but Reed's vision, diplomacy and attention to detail were instrumental in shaping it and keeping it on track.

For some scientists the decision to spend a sabbatical year in Washington D.C. doing administrative work at age 46 might have signaled a career transition from research per se to research administration and policy, but that was not the case for Reed. He saw his position as an opportunity to build bridges between scientists in the United States and the Soviet Union and as an investment in high quality atmospheric data sets that would be of use to the research community in the years ahead. He took a strong personal interest in the GATE, which was designed to elucidate the interaction between large-scale wave disturbances in the tropical atmosphere and the orgnized patches deep cumulus convection embedded within them. The waves were well resolved in the global numerical weather prediction models in use at that time, but convection occurs on space scales much too fine to be resolved. Reed also became interested in clear-air turbulence, which was recognized as the other important sub-grid scale physical process. He resolved to pursue these topics in his own future research.

Upon his return to UW, Reed began collaborating with turbulence specialist Kenneth Hardy on two case studies revealing the synoptic conditions that lead to widespread clear-air turbulence outbreaks. They demonstrated how clear-air turbulence develops spontaneously in layers of the atmosphere in which the vertical shear becomes so strong that the Richardson number drops below the critical value of 0.25. They also showed how vertical mixing of potential temperature gives rise to a distinctive signature of the turbulence layer in the thermal field, and how that signature may persist for many hours after the turbulence that produced it has subsided.

To gear up for his own participation in GATE, Reed undertook a study of the large-scale structure and evolution of tropical weather disturbances. Rather than studying Atlantic disturbances, he elected to focus on waves in the western Pacific, where there was a much more extensive network of upper-air stations. By this time, satellite imagery at visible wavelengths was providing daily snapshots of clusters of deep convective clouds embedded in synoptic-scale waves as they tracked westward across the Pacific. Reed showed that the waves extend through the depth of the troposphere and exhibit a mid-tropospheric phase reversal in the wind field.

Using the cloud clusters inferred from the satellite imagery as a frame of reference, Reed composited the wind and temperature fields at various levels through the depth of the troposphere to obtain vertical profiles at each station. A novel element of his analysis protocol was to estimate the divergence of the horizontal wind field using data for the "Kwajalein-Eniwetok-Ponape triangle" a variant of the "Bellamy triangle" by which he introduced students to kinematics in his synoptic meteorology courses. But in contrast to Reed's classroom teaching, which was largely based on graphical methods, his research computations were now performed digitally, with the help of support scientist, Ernest Recker. The Reed and Recker paper based on that analysis has proven to be one of the most widely cited papers on westward propagating wave disturbances in the tropical troposphere.

Concurrent with the Reed and Recker paper, I published a paper presenting similar results obtained exclusively through through the use of spectrum analysis. That my paper has been cited only about one fourth as many times as their much simpler and more accessible paper reminds me of Reed's advice that one shouldn't use a sledgehammer to swat a fly. Reed's sixth Ph.D. student, Richard Johnson, extended the analysis of the Pacific disturbances in Reed and Recker and went on to perform a more detailed study of the role of precipitation-induced downdrafts in mediating the interactions between deep cumulus convection and synoptic scale waves in the tropics.

In 1972, while Reed was serving as president of the AMS, he went on a lecture tour in the Soviet Union with Edward Lorenz and several other leading scientists.[7] During a boat tour on the Ob Sea Reed had occasion to become acquainted with Guri Marchuk, one of the Soviet Union's leading mathematicians who was then the Director of the Computer Center in "Academy Town" (a suburb of Novosibirsk) and later became the president of the Soviet Academy of Sciences. On that occasion, Marchuk proposed a 1-year, exchange between a scientist at the Computer Center and a scientist at the University of Washington. My wife and I very much enjoyed participating in that exchange.

In his role as President of the AMS, Reed laid the groundwork for the first visit by a delegation of U.S. meteorologists to China after it opened its doors to the western world; in 1974, and he and his wife had the privilege of taking part in that historic event. A detailed account of the U.S. delegation's experiences and their reflections on the things they had heard and seen is presented in Kellogg et al. 1974. At the beginning of their summary at the end of the article, the authors commented

> *The smiles of those around us from sun up until far into the evening seemed genuine and warm. [The strangers] who crowded around us on the streets of Peking, Shanghai, and Canton... often were attracted out of curiosity; each would stare at us until he or she caught someone's eyes and then there was a spontaneous smile.*

The field phase of the GARP Atlantic Tropical Experiment (GATE) also took place in 1974. Reed was stationed at the operational headquarters in Dakar, Senegal, where he served as an internationally appointed adviser to director, Joachim Kuettner, assisting with weather briefings and the day-to-day planning of flight operations. While there he developed lifelong friendships with Robert Burpee and Edward Zipser, with whom he shared operational responsibilities, research interests, and often a beer and peanuts at the nearby hotel after a long day's work.

In observing day-to-day sequences of weather while living in Dakar, Reed was intrigued by the regular passage of easterly waves that develop over Africa and propagate westward across the Atlantic, some developing into hurricanes. In the ensuing years he wrote several papers on easterly waves, which he later considered to be among his most important research contributions.

Richard J. Reed's service on Boards and Committees of the National Academy of Sciences / National Research Council

Member, Committee on Global Atmospheric Research Program, 1969.

Member, Committee to the National Oceanographic and Atmospheric Administration, 1970–73.

Chairman, U. S. Committee, for the Global Atmospheric Research Programme (GARP) 1975–76.

Chairman, Committee on Atm—ospheric Sciences and Climate, 1980–82.

Vice-Chairman, Board on Atmospheric Sciences and Climate, 1982–83.

Member, Commission on Physical Sciences, Mathematics and Applications, 1986–1989.

1976–1985: Closer to home

From the mid 1970s to the mid '80s, visits to distant countries accounted for a relatively smaller portion of Reed's travel. Most of his frequent flyer miles were logged on domestic trips to Washington D.C., where he served on numerous NAS/NRC advisory committees that provided oversight for the GARP as well as other national and international atmospheric research programs.

Reed's research interests also drew closer to home. One of his new thrusts—stimulated by his frequent visits to the department's map room to touch base with the local weather—was to examine the peculiar kinds of weather systems that affect the lives of residents of the Pacific Northwest. For example, on the morning of February 13, 1979 western Washington experienced a severe windstorm that caused most of the pontoons that kept the the Hood Canal Bridge afloat to capsize and sink, taking the bridge with them. Reed was asked by the Washington State Department of Transportation to work with a team of experts charged with identifying the factors that led to the bridge's collapse. For several weeks he drove around parts of the Olympic Peninsula in his beloved pickup truck, assessing the damage. To save time and taxpayer money he relied on the truck for his overnight accommodations.

Based on his damage survey and his analysis of synoptic charts at the time of the event, Reed showed that the damaging winds were caused by an intense extratropical cyclone whose low-pressure center was tracking northward in the offshore waters. As the low passed northward into Canada and pressures over western Washington began to rise sharply, a strong southward pressure gradient developed on the lee side of the Olympic Mountains. The Hood Canal Bridge is located in a region that is particularly susceptible to the strong surface winds that develop under these conditions.

Another study that Reed conducted around this time was an analysis of the foehn-like wind storms that occur in favored locations along the eastern side of the Puget Sound lowlands such as the small city of Enumclaw, WA, 70 km southeast of Seattle at the foot of the Cascade range. The high winds are observed during wintertime when cold anticyclones are lodged in the Columbia Valley (in central Washington), forcing a highly stratified airflow across the Cascades from east to west. Orographic enhancement occurs immediately to the west (downstream) of gaps in the mountain range, the most prominent of which is immediately to the north of Mt. Rainier and just upwind of Enumclaw.

Another of Reed's new interests was "polar lows" a term he used to denote cyclonic storms that develop in the polar airstream. In his frequent visits to the map room he noticed a series of distinctive comma-shaped features in the satellite imagery that came ashore on the Washington coast, about a day apart (Feb. 24–27, 1976), at a time when the primary frontal zone was located well to the south of the area. The clouds developed in a cool polar airstream in which the baroclinicity was modest but the stratification was quite unstable, with convection extending through much of the depth of the troposphere. The cloud bands in the satellite imagery were accompanied by troughs in the pressure field and front-like features, preceded by warm advection, and followed by cold advection.

In contrast to the occluded fronts that develop in the later stages of the life cycle of extratropical cyclones, as depicted in the Norwegian model, these so-called "instant occlusions" develop spontaneously in a region with no prior frontal history. The discussion in Reed's (1979) paper resulting from this study is reminiscent of his early conversations with Sanders and Danielsen about the limitations of the conceptual models derived from the Norwegian School. This paper exhibited many of the hallmarks of Reed's publications during this period. It was grounded in contemporary operational practices of weather analysis and prediction; it employed satellite imagery to document the distribution of cloudiness and precipitation; it made judicious use of labels to categorize and classify atmospheric phenomena; and it included a thoughtful theoretical interpretation in which the results of a case study were generalized.

Reed became convinced that the comma clouds developing off the Washington coast have some features in common with the tight, circular cyclones that develop occasionally over the Arctic, and he referred to both phenomena as manifestations of "polar lows." His classification scheme provoked a spirited, but friendly debate with Danish synoptic meteorologist Eric Rasmusson, who maintained that the comma clouds over the Pacific are not true polar lows. But despite their differing views regarding the terminology, Reed and Rasmusson shared a common view of the morphology of these storms. Reed's seventh Ph.D. student, Warren Blier, also was involved in some of these studies.

In the early 1980s Reed became interested in yet another special category of extratropical cyclone—the ones that deepen rapidly (with drops in central pressure of 1 millibar per hour or more, sustained over a 24-hour period). Many of these storms—referred to as "explosive deepeners" or "bombs" by Sanders and Gyakum, 1980 —attain central pressures as low as some tropical cyclones. Reed set out to identify the environmental conditions that distinguish these storms from their more slowly deepening counterparts. To address this question he eschewed the time honored "case study" and "compositing" methodologies in favor of designing experiments to be performed with numerical weather prediction models. As the time of his next sabbatical approached, he took time to familiarize himself with the recent literature on this topic.

Reed spent his third sabbatical year (1985–1986) as a visiting scientist at the European Centre for Medium-Range Weather Forecasting (ECMWF) in Reading, England. By this time the ECMWF had become the leading institution in the world in advancing the state of the art of weather prediction—and, by virtue of the close collaborations with Brian Hoskins and other scientists at the nearby University of Reading, it had also become a mecca for atmospheric dynamicists. With its proximity to the English countryside and also to London, Reading was a most hospitable place for an anglophile to spend a sabbatical year. Among Reed's best friends at ECMWF was Tony Hollingsworth, who shared his confidence that the impressive advances in the science of numerical weather prediction that they had witnessed during the past 20 years were only a foretaste of things to come.

Spirited competition

Reed was perennially busy at UW, but he could always find time during the spring quarter to compete for the coveted first prize in the departmental weather-forecasting contest. He had been instrumental in establishing this annual event as an optional supplement to the undergrauate curriculum and an integral part of the social fabric of the department. Reed managed to win the contest every year that he was in residence, but not without a few close calls. One of his more serious challengers was a graduate student by the name of Rob Farber, who enjoyed the competition as much as Reed did and liked to heckle Reed to try to get him "off his game." Most of Reed's and Farber's interactions were in the form of good-natured banter, but not entirely. Reed didn't mind Farber referring to him as "the old man," but to for him lose the contest to an impudent student would have been an embarrassment.

Another challenger was research professor, Robert Brown, who admittedly knew little about the art of weather forecasting, but he knew as well or better than Reed how to play the odds to optimize his score. Brown beat Reed at forecasting precipitation that year, and he claimed that he would have won the contest outright had it not been for a freak thunderstorm on the final day of the competition.

Reed was equally competitive when it came to sports, although in this arena he was usually more intent on breaking his own records than surpassing his opponents. Some days as a break from running, he and his faculty colleague, Frank Badgley would swim together at lunchtime. Part of their routine was to see how many laps they could swim underwater. One day, in a valiant effort to break his own previous record, Reed held his breath underwater so long that he passed out. Fortunately, Badgley was close by and pulled him out of the water in time to prevent serious harm.

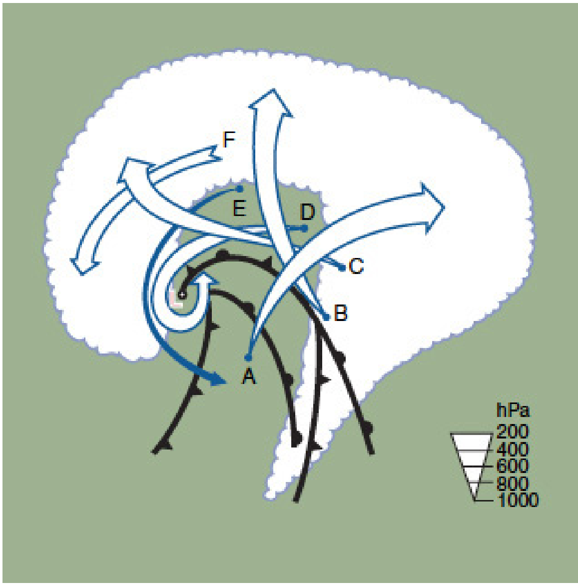
1986–2001: Bonus years

When he returned from his sabbatical year in Reading, Reed was old enough (64) to start planning for his retirement. But as it turned out, he enjoyed another 15 years of active engagement in research. His sabbatical year had been highly productive, and his experience at ECMWF had confirmed his belief that numerical weather-prediction models had become sufficiently reliable to justify their use in synoptic meteorology—not only for the description and diagnosis of weather systems, but also for testing hypotheses. He was convinced that these models could be effectively applied to the study of the effects of large-scale environmental conditions upon the evolution of extratropical cyclones and, in particular, to identify the conditions that lead to explosive cyclogenesis.

Before Reed went on the Reading sabbatical, Richard Anthes (president of the University Corporation for Atmospheric Research) had suggested that he consider collaborating with Ying-Hua (Bill) Kuo, then a junior scientist at the National Center for Atmospheric Research (NCAR), who had complementary skills and similar research interests. Upon his return, Reed contacted Kuo and they embarked on a long and productive research collaboration that resulted in numerous co-authored papers. Others involved in this work were George Grell, who spent a year at UW as a postdoc working with Reed; support scientist Mark Albright; and Reed's eighth and ninth graduate students, Mark Stoelinga and Jordan Powers, who rounded out his "baseball team" as he referred to his Ph.D. advisees. Reed relinquished his academic faculty position in 1991 to become an emeritus faculty member, leaving him free to spend a larger fraction of his time doing research. During the 1990s he made frequent trips to NCAR to collaborate with Kuo and Grell.

In contrast to most synoptic studies at the time, which relied mainly on observational datasets and operational analyses, Kuo and Reed made extensive use of numerical simulations performed with the Penn State/NCAR Mesoscale Model (MM4 and MM5). Their simulations yielded realistic patterns with greater spatial and temporal resolution and better dynamical consistency than the more conventional datasets used by their peers. After they had established the credibility of the model output field, other investigators followed suit, and the MM4 and MM5 became enormously popular mesoscale models in the research community, with over than 4,000 registered users at that time. Kuo attributes much of the success of their pioneering work to Reed's ability to convincingly relate features in the simulations to their counterparts in the real world through careful analysis and diagnosis.

One of the major themes in Reed's work during this period was the use of the analysis of three-dimensional, Lagrangian trajectories to reveal how the distinctive structural features of extratropical cyclones develop. He had applied Lagrangian diagnostics throughout his career, but working with state-of-the-art, high-resolution, dynamically consistent numerical models provided him with more numerous and more accurate trajectories than he had had access to in the past.



This idealized schematic is adapted Reed's work. It shows, in his words, "that the Lagrangian motion relative to a developing cyclone consists of two basic flows: an ascending warm flow in which the trajectories, depending on point of origin, spread either anticyclonically downstream or cyclonically upstream, and a corresponding descending cold flow in which the trajectories near the low center are intertwined with the cyclonic branch of the warm, ascending flow. In combination, the bundles rising and sinking trajectories can be crudely likened to a pair of interlocking fans."

Reed was particularly interested in applying trajectory analysis to study the formation of fronts, including the various types of occluded fronts that develop near the centers of mature cyclonic storms. A notable example was his study, with Kuo and Low Nam, of the thermal structure of an intense marine cyclone, making extensive use of three-dimensional air trajectories derived from a very fine mesh model simulation. Reed was intrigued with the remarkably strong thermal gradients along the occluded front. Their description of occluded front formation was at variance with classical Norwegian models, and with recent studies emphasizing the seclusion of a small blob of relatively warm air near the low center, reminiscent of the so-called "warm core" structure of tropical cyclones. Based on their trajectory analysis, Reed et al. concluded that these features developed in response to the deformation of the temperature field by the horizontal wind pattern in the developing cyclone.

The "take home message" of this study was the same as those of several of Reed's earliest papers, but in this case the features of interest were much more intricate. Such an accurate and detailed trajectory analysis could not have been performed without the use of a much more detailed and more realistic numerical simulation than Reed could have imagined in the early stages of his career.

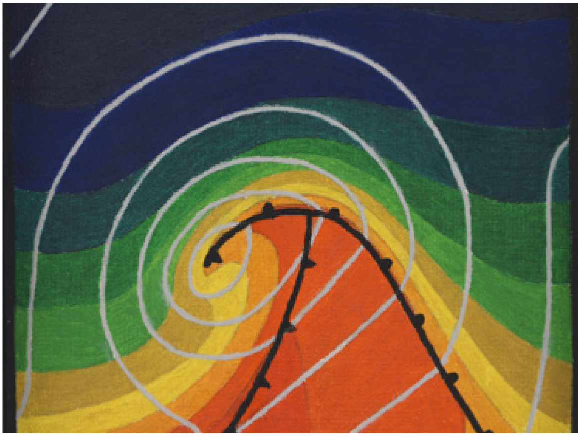
In these same numerical experiments, Reed and his colleagues explored the role of boundary fluxes at the air/sea interface in cyclone development. They showed that the upward fluxes of latent and sensible heat that occur prior to cyclone development act to "precondition" the thermodynamic environment for explosive cyclogenesis. But in contrast to the situation in tropical cyclones, the fluxes that occur while the storm is deepening proved to be relatively unimportant.

During these years, Reed divided his working time between UW and NCAR. He accumulated hundreds of thousands of frequent flier miles on United Airlines flying back and forth between Seattle and Denver, often on a weekly basis. When in Seattle, he and Joan enjoyed their home—a converted cottage, situated on the edge of a bluff with a sweeping view of Lake Washington, purchased back in 1973 during a brief interval when such properties were affordable to university professors. The property included a small orchard with several varieties of apple trees. Reed carefully documented each year's apple harvest and invited family members to annual tastings, at which he discussed in great detail, the attributes of each variety. Another notable annual event was the Reeds' holiday season open house, for which their home was beautifully decorated.

To maintain his physical fitness, Reed continued to swim regularly at the UW gym and wherever he could find a pool of known length, which would enable him to time himself. His daughter, Lisa recalled an incident that occurred at a resort hotel near Santa Barbara CA, where she and her family spent a few days visiting with her parents. When Reed swam his customary laps in the hotel pool he was, at first, gratified by how quickly he had been able to complete them. But upon reflection, he began to suspect that the pool might not be as long as advertised. To test this hypothesis, he needed to acquire the requisite data. Before long, he appeared with a tape measure and proceeded to make his own determination of the pool's length. There ensued a spirited conversation with the resort owner, who was, or at least appeared to be flabbergasted both by Reed's measurements and by the importance he attached to them.

2001–2006: History and art

In 2001 Reed suffered a series of spinal strokes that impaired his mobility and made it difficult for him to exert enough concentrated mental effort to continue to pursue his research. To keep busy and engaged, he decided to write a short memoir of his professional life, in which he recorded the events and people that shaped his career, dating back to his service in the Navy during World War II. He shared his memoir with his colleagues by publishing it as an American Meteorological Society (AMS) monograph. Some of the material for this present memoir was drawn from that source.



Oil painting by Reed circa 2003 depicting and occluded extra tropical cyclone with fronts branded in black, sea level pressure isobars in light gray, and isotherms as borders between the bands of colored shading.

In 2003 a symposium in honor of Reed was convened at the AMS annual meeting; he was able to take part in the event and clearly enjoyed interacting with long-term friends, colleagues, and former students. This event also marked the climax of Reed's active involvement in the AMS, which began when, as an MIT graduate student, he was enlisted to serve as a ballot teller. This involvement, which included his distinguished service in 1972 as AMS President, continued throughout his career.

Reed was the recipient of its Meisinger Award (1964), Second Half Century Award (1972), Charles Franklin Brooks Award (1983), and its Carl-Gustav Rossby Research Medal (1989). He was later designated an Honorary Member of the AMS.

In his retirement Reed also took up oil painting. Like his friend, Ed Danielsen and another of his synoptic meteorology colleagues, Melvyn Shapiro, he used this medium to express his aesthetic appreciation of the invisible flow patterns that shape our day-to-day weather. Unlike the weather maps that he drew in the synoptic lab, Reed's paintings are enlivened by bright colors and they are free of the wiggles imposed by noisy data.

Throughout his life, Reed was very much engaged in social causes. For example, although he had enlisted in the Navy during World War II and had enjoyed collaborating with the Navy and other branches of the armed forces throughout his professional career, Reed was deeply concerned about the excessive use of military power. He had opposed the Vietnam War and, together with Robert Fleagle[8] and other departmental colleagues, had participated in peaceful anti-war protests. Later in his life he was active in promoting domestic legislation designed to curb gun-related violence.

In January, 2008 I spent an evening with Reed in his and Joan's apartment. Our lively discussion about the development of the field of atmospheric sciences was illuminated by his recollections of people and events. We had had many similar conversations in the past, but this was the best of them. I remember regretting afterward that I hadn't come prepared to record it. Reed died two weeks later.

Reed's legacy to the atmospheric sciences

Reed helped to bring about the transformation of weather prediction from an art into a science. Although his research mainly addressed atmospheric phenomena rather than weather forecasting per se, most of his papers were motivated by the long-term goal of improving the skill of operational weather prediction. He conceived many of his studies in the map room, while poring over the day's satellite imagery and analysis and forecast products and when he wrote his work up for publication, he framed the paper, at least in part, from the perspective of the forecaster.

While the scientific methodologies that he used always reflected the rapidly advancing state of the art, Reed's research papers and his teaching continued to convey the primitive, "right brain" sense of wonder that comes from witnessing the weather evolving in real time and trying to interpret it. He sensed a growing tension between the increasing numbers of academic researchers who, like himself, embraced and worked to advance state-of-the-art weather forecasting techniques, and the many practitioners, who saw their roles being marginalized by the ever-expanding array of computer-generated forecast products. Though the field was evolving, Reed remained convinced that the forecaster should continue to play a key role in evaluating computer-generated forecast guidance and interpreting it in terms of local conditions. Thus in his roles as AMS President and as a member of its executive committee, Reed strongly advocated keeping forecasters involved in the mainstream of the activities of the Society.[9]

Reed took pride in having contributed to the late 20th century breakthroughs in observing the atmosphere, understanding atmospheric phenomena, and achieving a level of forecast skill that was unimaginable at the time he entered the field. Yet he acknowledged that despite these advances, weather forecasting would always be a competitive game with human contestants, however well-trained and experienced, pitted against the vagaries of nature.

Reed preferred to work as an individual or as a member of a small research team, without engaging in formal long-range “strategic planning” exercises or commitments to specific “deliverables.” Yet he foresaw that in order to design and implement advanced observing systems for weather and climate; to access, process and analyze the ever increasing volume of raw data that these systems would generate; and to justify these large public investments in scientific infrastructure; it would be necessary for federal agencies and nations to cooperate and collaborate much more extensively than in the past. He thus saw “little science” and “big science” as complementary enterprises that could flourish side by side.

During the 1960s and ‘70s, the GARP was the umbrella under which large, coordinated projects in the atmospheric sciences were conceived and organized. From the 1980s onward, much of the planning and coordination for U.S. participation in large projects has been overseen by the National Research Council: its Committee (and later, its Board) on Atmospheric Science and Climate. Reed served terms as a member and sometimes as chair of these committees and he was often called upon to review their reports.

Reed is also fondly remembered as a teacher and mentor. His admonitions, rendered in his Boston native accent —such as “You can’t put the isobaahs on the chaaht that way” still rings in the ears of his former MS student John Perry (1958), who recalls his “half hour conferences with [Reed] that gave you both a week’s worth of work and the confidence to tackle it.” In addition to mentoring his own 40 MS and 9 Ph’D students, Reed took an active interest in the career development of his younger departmental colleagues, Holton, the author, and Houze[10] in the late 1960s and ‘70s; Mass in the 1980’s; and Kuo in the 1990s—unselfishly taking the time to offer constructive critiques of our textbooks and research papers.

Like his own mentors in the Navy, Reed inspired others to value and develop their own talents by setting a good example. His scientific papers are exemplars of lucid expository writing: straightforward, unpretentious, and devoid of idle speculation and gratuitous technical details. They place his own work in historical context and they show a deep appreciation of the contributions of others. They reflect his lively curiosity, his reverence for the natural world, his openness to unorthodox ideas, and his high standards for what constitutes a “proof.”

Although Reed became a member of the scientific elite, he never forgot his own humble background. Kuo recalls:

> *Professor Reed was a well-established and well-known scientist, with great accomplishments and credentials, yet when we worked together he treated me as his equal. In fact, he treated everyone with kindness and respect, including our administrative and support staff. He taught me that in order to become a great scientist, first, you have to be a great human being.*

Reed was deeply grateful for the free college education that he received while he was in the Navy during World War II. As a token his of gratitude, he and his wife, Joan established but anonymously endowed a scholarship fund for undergraduate students in the UW's Department of Atmospheric Sciences.

NOTES

1. Krick was pressured into resigning from the AMS because of questionable business practices in marketing his long-range forecasts and weather modification services. Many years later, while Reed was serving as a councilor, the AMS was faced with an analogous situation, but this time, on the advice of legal counsel, the Council voted not to pursue the matter Reed and Jerome Namias cast the two dissenting votes. Reed later acknowledged that under the circumstances, the Council probably made the right decision. For an interesting epilogue to this story, see the transcript of Reed's (1990) taped interview with Earl Droessler http://nldr.library.ucar.edu/repository/assets/ams/AMS-000-000-000-176.pdf
2. Lance Bosart, an MIT graduate student during the late 1960s "felt privileged to listen in on several 'spirited discussions' between Reed and Sanders [in which they] would 'argue' about science and the weather for what seemed like hours."
3. Around the same time, Reed's MS student, John Perry fulfilled his thesis requirement by developing a computer code that was capable of producing a reasonably successful objective analysis of an upper level frontal system.
4. Richard Lindzen credits with Reed with getting him interested in atmospheric tides.
5. The photo accompanied an article by Reed entitled, "Flying Saucers Over Mt. Rainier," documenting the conditions under which lenticular clouds formed and arguing that a prior alleged flying saucer sighting by the pilot of a light plane flying in the vicinity of Mt. Rainier was probably of the same kind of lens-shaped clouds. In his autobiographical monograph, Reed noted, "Needless to say, this proposal had no impact on the true believers. In fact, it enraged some. I have always been proud of this offbeat paper and disappointed that it has not received greater notice in the literature on the subject. I freely admit to having a passionate dislike of UFOs, sasquatches, Loch Ness monsters, and other products of deluded minds."
6. Other members of the US Committee for the Global Atmospheric Research Program at that time included Richard Goody, Gordon J.F. MacDonald, Tom Malone, Walter Munk, Owen Phillips, and Henry Stommel. Robert M. White was listed as an invited participant. (Perry 2003).
7. During their time in the USSR Reed and Lorenz shared a hotel room. Reed marveled how, at each stop on the tour. Lorenz would get up early in the morning and update his lecture, inserting new numerical experiments for which he did the calculations in his head or manually.
8. Reed and Fleagle and their families were active members of the University Unitarian Church, which for many years has been one of Seattle's focal points for social action on peace and social justice issues.

9. http://nldr.library.ucar.edu/repository/assets/ams/AMS-000-000-000-176.pdf
10. Houze recalls that Reed's advice (if one can call it that) often took the form of seemingly unobtrusive, yet deep and thoughtful questions that the authors were left to answer for themselves.

GRADUATE STUDENTS

Ph.D.

Blier, Warren	1989
Danielsen, Edwin Frederick	1957
Johnson, Richard Harlan	1975
Kreitzberg, Carl William	1963
McKenzie, Donald Johnson	1968
Muench, Harry Stuart	1964
Perry, John Stephen	1966
Powers, Jordan Gray	1994
Stoelinga, Mark T.	1993

M.S.

Albright, Mark David	1982
Azim, Kaleen	1963
Bjorem, David Lee	1966
Campbell, William Joseph	1958
Cohick, Mikel William	1967
Dickey, Woodrow W.	1960
Dickinson, Lee George	1963
German, Kenneth Edgar	1959
Haglund, George Thomas	1968
Hammond, George Randall	1966
Hansen, Donald Clarence	1961
Hopkins, Robert Harold	1963
Jaffe, Kenneth Drew	1982
Kampworth, Donald Henry	1964
Kelley, Walker Emanuel Jr.	1974
Kunkel, Bruce Arlen	1959
Lewis, Robert Mering	1982
Lin Ray-Gew (Qing)	1983
Lord, Roddee Edward	1960
McGarry, Mary Matson	1977
Mullen, Steven Lee	1978
Newell, Paul C.	1972
Nishimoto, Hiroshi	1961
Norquist, Donald C.	1976
O'Neal, Joe Roberts	1959
Payne, Steve William	1978
Perry, John Stephen	1960
Potter, Thomas Duane	1957
Powers, Jordan Gray	1991
Roddy, Mark Robert	1987
Rogers, Dale Graham	1963
Schoenberg, Sally Ann	1982
Start, George Eugene	1966
Tank, William Genrich	1955
Thompson, Robert Morse Jr.	1977
Try, Paul David	1966
Tung, Yea Ching	1990
Williams, Nolan Patrick	1959
Wilson, Richard Keith	1958
Wolfe, John Leon	1961

REFERENCES

Blair, T. A. 1937. *Weather elements.* Upper Saddle River, NJ: Prentice Hall.

Droessler, E. 1990. Interview of Richard Reed. [AMS63]. Tape-recorded interview project. Boston, MA/Boulder, CO: American Meteorological Society / University Corporation for Atmospheric Research.

Fleagle, R. G. 2001. *Eyewitness to the atmospheric sciences*. Boston, MA: American Meteorological Society.

Hammond, G. R. 1967. *Study of a left moving thunderstorm of 23 April 1964*. ESSA Tech. Memo. IERTM-NSSL-31. Norman, OK.

Hoskins, B. J. 2003. Back to frontogenesis. *Meteorological Monographs* 31(53):49–59.

Kellogg, W.W., D. Atlas, D. S. Johnson, R. J. Reed, and K. Spengler 1974. Visit to the Peoples' Republic of China: A report from the AMS. delegation. *Bull. Amer. Meteorol. Soc.* 55:1291–1330.

Klemp, J. B. and R. B. Wilhelmson 1978. Simulations of left- and right- moving storms produced by storm splitting. *J. Atmos. Sci.* 35:1097–1110.

Panofsky, H. A. and G. W. Brier 1958. *Some applications of statistics to meteorology.* State College PA: Mineral Industries Extension Services, College of Mineral Industries, Pennsylvania State University.

Perry, J. 2003. A life in the global atmosphere: Dick Reed and the world of international science. *Meteorological Monographs* 31(53):131–138.

Reed, R. J. 2003. A short account of my education, career choice, and motivation. *Meteorological Monographs* 31(53):1–7.

Sanders, F. and J. R. Gyakum 1980. Synoptic-dynamic climatology of the "bomb." *Monthly. Weather. Review* 108:1589–1606.

Veryard R.G. and R.A. Ebdon 1961. Fluctuations in tropical stratospheric winds. T*he Meteorological Magazine* 90:125–143.

SELECTED BIBLIOGRAPHY

1950 The role of vertical motions in ozone-weather relationships. *Journal of Meteorology* 7:263–267.

1953 With F. Sanders. An investigation of the development of a mid-tropospheric frontal zone and its associated vorticity field. *J. Meteorol.* 10:348–349.

1955 A study of a characteristic type of upper level frontogenesis. *J. Meteorol.* 12: 226–237.

1959 Flying saucers over Mount Rainier. *Weatherwise* 11:43–46.

1961 With W. J. Campbell, L. A. Rasmussen, and D. G. Rogers. Evidence of a downward-propagating annual wind reversal in the equatorial stratosphere. *J. Geophys. Res.* 66:813–818.

1966 With D. J. McKenzie and J. C. Vyverberg. Diurnal tidal motions between 30 and 60 kilometers in summer. *J. Atmos. Sci.* 23:416–423.

1971 With E. E. Recker. Structure and properties of synoptic scale wave disturbances in the equatorial Western Pacific. *J. Atmos. Sci.* 28:1117–1133.

1972 With K. R. Hardy. A case study of persistent, intense, clear air turbulence in an upper-level frontal zone. *J. Appl. Meteorol.* 11: 541–549.

1977 With D. C. Norquist and E. E. Recker. The structure and properties of African wave disturbances as observed during Phase II of GATE. *Mon. Wea. Rev.* 105:317–333.

1979 Cyclogenesis in polar air streams. *Mon. Wea. Rev.* 107:38–52.

1980 Destructive winds caused by an orographically induced mesoscale cyclone. *Bull. Amer. Meteorol. Soc.* 61:1346–1355.

1981 A case study of a Bora-like windstorm in western Washington. *Mon. Wea. Rev.* 109:2383–2393.

1988 With E. Klinker and A. Hollingsworth. The structure and characteristics of African easterly waves disturbances as determined from the ECMWF Operational Analysis/Forecast system. *Meteororol. Atmos. Phys.* 38:22–33.

1992 With Y.-H. Kuo and S. Low-Nam. Thermal structure and airflow in a model simulation of an occluded marine cyclone. *Mon. Wea. Rev.* 120:2280–2297.