

## HELEN S. HOPFIELD (1899–1989)

By Harold D. Black

Helen S. Hopfield, a retired senior physicist at APL, died on January 16, 1989, at age 89. Helen had joined the Laboratory in 1943 and worked until her “retirement” in 1976, when she changed to part-time employment that continued until late 1980.

She was a native of Fort Atkinson, Wis. In 1921 she earned an A.B. from Colorado College, and in 1924 an M.A. in physics from Mount Holyoke College. For the next several years, she was an instructor in physics and mathematics at Winthrop College in South Carolina. From 1926 to 1928, she was a teaching fellow in physics at the University of California, Berkeley. She was the widow of John J. Hopfield, Sr., renowned in his own right for the discovery of several bands in the solar UV spectrum. She was the mother of three children and the stepmother of three. Among her survivors are her children, 30 grandchildren, and 20 great-grandchildren.

These are the stark outlines of Helen Hopfield’s life, but to her friends and colleagues she was much more.

My first memories of Helen Hopfield date from 1961. We were both members of a loosely knit group that was struggling to implement a large software system for determining the orbit of an artificial satellite. In retrospect, it was an exciting time, but it didn’t seem so then. We were hard-pressed, stretched to the limit of our abilities and pushing hard on the available computer resources of that era.

I had managed, with help from my colleagues, to derive some perturbations to the orbit. I then worked with Joy Hook to implement the equations in a nonlinear, least-squares fitting algorithm to fit the theory to the data. After several false starts and the terrors associated with subtle bugs, the process converged. The catharsis came with seeing the plotted results, adequate proof (for me) that my analysis was correct and, moreover, that it was a realistic model of the real world. I told a friend of my results, and sometime later he said that Helen had another validation of my analysis. I was a bit nonplussed but appreciated the support from wherever it came. Helen explained what she had done and why it looked good to her. I did not understand all the details but had no reason to question her results!

Our contacts became more frequent. Bill Guier had asked Helen to look into the effect of near-atmosphere (tropospheric) refraction on our satellite-based Doppler tracking data. I wasn’t very sanguine about this, because it was a weather problem and I couldn’t see any way to make sense out of a “weather-like” phenomenon—my euphemism for a technical swamp where we could be bogged down forever. Shortly, however, I heard that Helen’s analysis was really “working.” [My immediate concern was integrating all the software modules into a consistent program architecture. The existing physical models limited the orbit accuracy to about 150 meters. Any effect less than 15 meters was unimportant, and I reckoned that the refractive effect was peanuts.]

Since Helen’s analysis was making sense, I had to see if it deserved serious attention. She told me that, without care, the tropospheric effect could cause errors as large as several hundred meters; by eliminating data at the extreme elevation angles, we could limit the associated errors to 50 meters. This was useful and certainly not peanuts. Even with her fix, the remaining errors were an appreciable fraction of the error budget.

She continued to work on tropospheric refraction for 18 years, until 1980. Her basic style was to examine great amounts of data and to test her theoretical formulations at every step of the analysis against those data. She insisted on hand-plotting everything. Using this process, she developed increasingly more accurate models of the tropospheric correction. Her most significant findings were published when she was 70 years old (*Rad. Sci.* 6, Mar 1971). Over the years, she had developed enough understanding to make sense out of a weather-associated phenomenon; from the literature she gleaned a model of the refractive index at radio frequencies.<sup>1</sup>

The model was the sum of two terms: one due to the dry atmosphere, and one due to the water vapor. She sized the problem and noted that the dry term was typically 10 times as large

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as the wet. She then noticed that the dry term was a constant times the pressure/temperature ratio, and that if she invoked the perfect gas law, this ratio was the air density at a point. She then assumed that the atmosphere was in hydrostatic equilibrium and integrated the density along the vertical, which was necessary to compute the range correction from the refractive index. The computation yielded a constant times the surface pressure, with no assumptions about pressure and temperature profiles. This understanding was valuable and useful in its own right—fortuitously so, because the surface pressure at a site is nearly constant, usually varying no more than a few tenths of a percent. She tidied this up and told me that the dry correction along the vertical should be about 2.3 meters for a site at sea level.

The correction for site altitude was a hydrostatic one, easily computed. She continued: If we knew the correction along the vertical, we would know it everywhere for a given transit of a low-altitude satellite. The atmosphere could be assumed to be spherically stratified, and an integral over the observer-satellite line would extend the vertical correction to other geometries. It was this geometrical integral that parlayed the 2.3 meters to an extreme 25-meter correction. Just how to attack this integral eluded us for a long time, but it eventually fell into place.

Helen's work gradually gained recognition, particularly after the 1971 paper; she was invited to present papers—and did present them—at international meetings, one in The Netherlands in 1976 and another before The Royal Society of London in 1978.

In her relationships with colleagues, she was kind, quiet, and unobtrusive. When challenged technically, she was formidable. She did not hesitate to tell an assertive challenger, "I do understand what you are saying; your arguments are half-baked." She suffered the prejudices against women in a male-dominated environment, and she enjoyed the professional and financial recognition that came to her late in life.

Around 1979, her arthritis became so painful that she could not comfortably walk; pragmatic as ever, she acquired a motorized three-wheeler and rode around the Laboratory. She enjoyed what she was doing, did it well, and did it as long as she could. She did not "go gentle into that good night."

Her mind remained as sharp as ever; when she was 80 years old she still remembered the Latin names of flowers, even the unusual ones. She was an inspiration to us all.

#### REFERENCE

- <sup>1</sup> Smith, E. J., Jr., and Weintraub, S., "The Constants in the Equation for Atmospheric Refractive Index at Radio Frequencies," *Proc. IRE* 41, 1035-1037 (1953).



Helen S. Hopfield at her desk in September 1975. The flowers were a gift on the occasion of her 75th birthday.

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