

OBITUARIES

Thomas B. Sanford

Physical oceanographer Thomas B. Sanford died from heart failure on 12 July 2020 in Seattle, Washington. He was an innovative scientist who pioneered a suite of measurement techniques that use motional electromagnetic induction and have revealed new facets of ocean physics. For his contributions, Tom was awarded the American Meteorological Society's Henry Stommel Research Medal in 2010 and the US Navy's SECNAV/CNO Chair of Oceanographic Sciences in 2008.

When Michael Faraday lowered electrodes into the river Thames in 1832, he doubtless thought he was ushering in a new era of fluid-transport measurements. But the inventor of the electric motor and discoverer of electromagnetic induction was mistaken. His equipment had limited sensitivity and the conducting riverbed reduced the amplitude of the motional signal, so Faraday's measurement did not in fact quantify the river's flow.

Later experimenters verified that seawater flowing through Earth's magnetic field produced voltages that could be measured using electrodes attached to submarine telegraph cables or towed behind a ship. But the interpretation of those measurements continued to present challenges and provoke disagreements until Tom's 1967 PhD thesis, "Measurement and interpretation of motional electrical fields in the sea." Tom's theory correctly determined the appropriate simplifications for geophysical flows and the different interpretations of voltage measurements from fixed, towed, drifting, or vertically falling platforms. That enabled the exploration of the vertical, horizontal, and temporal structure of the ocean velocity field on which he built his career.

Born on 22 April 1940 in Toledo, Ohio, Tom received his bachelor's in physics from Oberlin College in 1962 and his PhD from MIT in 1967 under William von Arx. Undaunted by the fact that previous generations had essentially given up on getting anything useful from motionally induced voltages, Tom set out to build the

instruments that would reestablish geomagnetic induction as a viable tool and uncover a wealth of dynamical processes in the ocean. He did that work first at the Woods Hole Oceanographic Institution and then at the University of Washington's Applied Physics Laboratory.

Tom's theory and careful experimental methods in 1969–75 led to the establishment of submarine cable monitoring of the Florida Current—the headwaters of the Gulf Stream and a key component of the North Atlantic Gyre circulation. His work resulted in what is now one of the longest continuous time series of ocean transport.

With the free-falling electromagnetic velocity profiler, Tom and engineers Robert Drever and John Dunlap set out in the late 1960s to measure the electrical signals from vertical gradients of horizontal water velocity as small as 1 mm/s over a few meters of depth. They realized that the instrument required a sensitivity of 40 nV, a difficult challenge for an autonomous instrument then. Tom's success in decomposing the profiles into oppositely polarized spirals, sometimes called the oceanographer's double helix, revealed the predominantly downward propagation of internal waves, as expected from wind forcing at the surface. In collaboration with one of us (Gregg), Tom built a composite velocity and microstructure profiler that established a widespread relationship between internal wave shear and turbulence. That relationship underpins our current understanding of how vertical mixing occurs in most of the ocean interior.

Although customized instruments were Tom's specialty, he also wanted his motional induction techniques to help the broader oceanographic community. The adaptation of his profiler to a low-cost expendable format enabled multiple groups in the 1990s and 2000s to use it for surveys of internal waves, eddies, and energetic dense gravity currents that form in intermediate and deep waters of the world's oceans. Subsequent air-deployable versions captured the intense upper-ocean response to hurricanes. In 2004 Tom's group added velocity-measurement and air-deployment capabilities to robotic profilers that could send data ashore via satellite. They have now been used in long-duration studies; in hostile and remote environments, including under tropical storms and Antarctic ice; and in concen-



COURTESY OF THE SANFORD FAMILY

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trated swarms to simultaneously capture spatial and temporal variability.

Tom's innovations continued unabated. In 1995, for example, he used a fixed magnet and a set of electrodes in a vertical plane to quantify the horizontal vorticity of the flow; that work led to a new characterization of boundary-layer stress and its scales. In 2008 Tom developed a controlled-source electromagnetic sounding device for remote measurement of the conductivity profile in the water column. And his motional induction transport instrument was incorporated in 2014 into a seafloor fiber-optic network for real-time telemetry of ocean variability.

Even after retiring in 2015, Tom continued to work on new projects. Most recently he was developing creative approaches to analyze autonomous-profiler data; that paper will be published posthumously.

Tom's work was always highly collaborative, and he inspired his team of engineers to use unorthodox problem-solving approaches and create truly novel devices. He was a gracious contributor of observational data and insight to fellow scientists across the US and the world; he often let students and collaborators take first authorship on papers describing his best results. And he worked tirelessly to pass on his wisdom to others, including at least 23 students in their graduate and postdoctoral work. He will be sorely missed.

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