

# Walter Munk

**Walter Heinrich Munk** (born October 19, 1917) is an American physical oceanographer.<sup>[1]</sup> He is professor of geophysics emeritus and holds the Secretary of the Navy/Chief of Naval Operations Oceanography Chair at Scripps Institution of Oceanography in La Jolla, California.

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## Early life

Born in 1917 in Vienna, Austria-Hungary, Munk was sent to a boys' preparatory school in upper New York state in 1932.<sup>[2][3]</sup> The family selected New York because they envisioned a career in finance for Munk in a New York bank with connections to the family business. His father, Dr. Hans Munk, and his mother, Rega Brunner, divorced when Munk was a child. His maternal grandfather was a prominent banker and Austrian politician, Lucian Brunner (1850–1914). His stepfather, Dr. Rudolf Engelsberg, was briefly a member of the Austrian government of President Engelbert Dollfuss.<sup>[4]</sup>

## Walter Heinrich Munk



Munk in Stockholm in 2010 to accept his Crafoord Prize.

<b>Born</b>	October 19, 1917 Vienna, Austria-Hungary
<b>Nationality</b>	USA
<b>Awards</b>	Maurice Ewing Medal (1976) Alexander Agassiz Medal (1976) National Medal of Science (1985) William Bowie Medal (1989) Vetlesen Prize (1993) Kyoto Prize (1999) Prince Albert I Medal (2001) Crafoord Prize (2010)
<b>Scientific career</b>	
<b>Fields</b>	Oceanography, geophysics
<b>Doctoral advisor</b>	Harald Ulrik Sverdrup
<b>Doctoral</b>	Charles Shipley Cox

Munk worked at the firm for three years and studied at Columbia University. He hated banking, and left the

students

firm to attend the California Institute of Technology, where he earned a B.S. (1939) in physics. He applied for a summer job at the Scripps Institution of Oceanography in La Jolla, California.<sup>[4]</sup> The next year the director of Scripps, the distinguished Norwegian oceanographer Harald Ulrik Sverdrup, accepted him as a doctoral student, but told Munk that he did "not know of a single job in oceanography which would become available in the next decade".

Munk completed an M.S. in geophysics at the California Institute of Technology <sup>[5]</sup> in 1940 and a PhD in oceanography from the University of California, Los Angeles, in 1947. After graduation, Scripps hired him as an assistant professor of geophysics. He became a full professor there in 1954.

In 1968 Munk became a member of JASON, a panel of scientists who advise the U.S. government.

On June 20, 1953, Munk married Judith Horton. She was an active participant at the Scripps Institution of Oceanography for decades, where she made major contributions to architecture, campus planning, and the renovation and reuse of historical buildings. She and Walter were frequent traveling companions. Judith Munk died on May 19, 2006. Munk married La Jolla community leader Mary Coakley in June 2011. He turned 100 in October 2017.<sup>[6]</sup>

## War activities

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Munk applied for American citizenship in 1939 after the Anschluss and enlisted in the ski troops of the U.S. Army as a private. This was unusual as all the other young men at Scripps joined the U.S. Naval Reserve. Munk was eventually excused from military service to undertake defense-related research at Scripps. He joined several of his colleagues from Scripps at the U.S. Navy Radio and Sound Laboratory, where they developed methods related to amphibious warfare. Their methods were used successfully to predict surf conditions for Allied landings in North Africa, the Pacific theater of war, and on D-Day during the Normandy invasion.<sup>[4]</sup> Munk commented in 2009, "The Normandy landing is famous because weather conditions were very poor and you may not realize it was postponed by General Eisenhower for 24 hours because of the prevailing wave conditions. And then he did decide, in spite of the fact that conditions were not favorable, it would be better to go in than lose the surprise element, which would have been lost if they waited for the next tidal cycle two weeks."<sup>[7]</sup>

## The Institute of Geophysics and Planetary Physics in La Jolla, IGPP/LJ

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Returning to Scripps from a sabbatical at Cambridge University in England, in 1956 Munk developed plans for a La Jolla branch of the Institute of Geophysics, then a part of the University of California, Los Angeles. With the new branch of IGP, an institution of the wider University of California system, to be focused on planetary physics with an emphasis on the Earth-Moon system, IGP changed its name to the Institute of Geophysics and Planetary Physics, IGPP. IGPP at La Jolla was built between 1959–1963 with funding from the University of California, the U.S. Air Force Office of Scientific Research, the National Science Foundation, and private foundations,<sup>[8]</sup><sup>[9]</sup> The redwood building was designed by architect Lloyd Ruocco, in close consultation with Judith and Walter Munk. The IGPP buildings have become the center of the Scripps campus. Among the early faculty appointments were Carl Eckart, George Backus, Freeman Gilbert and John Miles. The eminent geophysicist Sir Edward "Teddy" Bullard was a regular visitor to IGPP. In 1971 an endowment of \$600,000 was established by Cecil Green to support visiting scholars, now known as Green Scholars. Munk served as director of IGPP/LJ from 1963–1982.

In the late 1980s, plans for an expansion of IGPP were developed by Judith and Walter Munk, and Sharyn and John Orcutt, in consultation with a local architect, Fred Liebhardt. The Revelle Laboratory was completed in 1993. At this time the original IGPP building was renamed the Walter and Judith Munk Laboratory for Geophysics. In 1994 the Scripps branch of IGPP was renamed the Cecil H. and Ida M. Green Institute of Geophysics and Planetary Physics.

## Research

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After World War II Munk helped to analyze the currents, diffusion, and water exchanges at Bikini Atoll in the South Pacific, where the United States was testing nuclear weapons.

### Wind driven gyres

Munk pioneered research on the relationship between winds and ocean circulation, coining the now widely used term "wind-driven gyres."<sup>[10]</sup>

### Rotation of the Earth

Munk was the first to show rigorously why one side of the Moon always faces the Earth (Munk and McDonald, 1960; and later papers up to 1975), a phenomenon known as tidal locking. Lord Kelvin had also considered this question, and had fashioned a non-quantitative answer being roughly correct. The Moon does not have a molten liquid core, so cannot rotate through the egg-shaped distortion caused by the Earth's gravitational pull. Rotation through this shape requires internal shearing, and only fluids are capable of such rotation with small frictional losses. Thus, the pointy end of the "egg" is gravitationally locked to always point directly towards the Earth, with some small *librations*, or wobbles. Large objects may strike the Moon from time to time, causing it to rotate about some axis, but it will quickly stop rotating. All frictional effects from such events will also cause the Moon to regress further away from the Earth.

In the 1950s, Munk investigated irregularities in the Earth's rotation, such as the Chandler wobble and annual and long-term changes in the length of day (rate of the Earth's rotation), to see how these were related to geophysical processes such as the changes in the atmosphere, ocean, and core, and the energy dissipated by tidal acceleration. He also investigated how western boundary currents, such as the Gulf Stream, dissipated planetary vorticity. His inviscid theory of these currents did not have a time invariant solution; no simple solution to this problem has ever been found.

### Project Mohole

In 1957, Munk and Harry Hess suggested the idea behind Project Mohole: to drill into the Mohorovicic Discontinuity and obtain a sample of the Earth's mantle. While such a project was not feasible on land, drilling in the open ocean would be more feasible, because the mantle is much closer to the sea floor. Initially led by the informal group of scientists known as the American Miscellaneous Society (AMSOC, including Hess, Maurice Ewing, and Roger Revelle),<sup>[3]</sup> the project was eventually taken over by the National Science Foundation (NSF). Initial test drillings into the sea floor led by Willard Bascom occurred off Guadalupe Island, Mexico in March and April 1961.<sup>[11]</sup> The project became mismanaged and increasingly expensive after Brown and Root won the contract to continue the effort, however, and Congress discontinued the project toward the end of 1966.<sup>[12]</sup> While Project Mohole was not successful, the idea led to projects such as NSF's Deep Sea Drilling Program.<sup>[13]</sup>

### Ocean swell

Starting in the late 1950s Munk returned to the study of ocean waves, and, thanks to his acquaintance with John Tukey, he pioneered the use of power spectra in describing wave behavior. This work culminated with an experiment that he led in 1963 to observe waves generated by winter storms in the Southern Hemisphere and traveling thousands of miles throughout the Pacific ocean. To trace the path and decay of waves as they propagated northward, he established stations to measure waves from islands and at sea (on R/P FLIP) along a great circle from New Zealand to Alaska. Munk and his family spent nearly the whole of 1963 on American Samoa for this experiment. Walter and Judith Munk collaborated in making the film "Waves Across the Pacific" to document the experiment.<sup>[14]</sup> The results showed little decay of wave energy with distance traveled.<sup>[15]</sup> This work, together with the wartime work on wave forecasting, led to the science of surf forecasting, one of Munk's best-known accomplishments.<sup>[7]</sup> Munk's pioneering research into surf forecasting was acknowledged in 2007 with an award from the Groundswell Society, a surfing advocacy organization.<sup>[16][17]</sup>

## Ocean tides

Between 1965 and 1975 Munk turned to investigations of ocean tides, being partially motivated by their effects on the Earth's rotation. Modern methods of time-series and spectral analysis were brought to bear on tidal analysis, leading to the development of the "response method" of tidal analysis.<sup>[18]</sup> With Frank Snodgrass, Munk developed deep-ocean pressure sensors that could be used to provide tidal data far from any land.<sup>[2][19]</sup> One highlight of this work was the discovery of the semidiurnal amphidrome midway between California and Hawaii.<sup>[20]</sup>

## Ocean acoustic tomography

Beginning in 1975, Munk and Carl Wunsch of the Massachusetts Institute of Technology pioneered the development of acoustic tomography of the ocean.<sup>[21]</sup> With Peter Worcester, Munk developed the use of sound propagation, particularly sound arrival patterns and travel times, to infer important information about the ocean's large-scale temperature and current. This work, together with the work of other groups,<sup>[22]</sup> eventually motivated the 1991 "Heard Island Feasibility Test", to determine if man-made acoustic signals could be transmitted over antipodal distances to measure the ocean's climate. The experiment came to be called "the sound heard around the world." During six days in January 1991, acoustic signals were transmitted by sound sources lowered from the M/V Cory Chouest near Heard Island in the southern Indian Ocean. These signals traveled half-way around the globe to be received on the east and west coasts of the United States, as well as at many other stations around the world.<sup>[23]</sup> The follow-up to this experiment was the 1996–2006 Acoustic Thermometry of Ocean Climate (ATOC) project in the North Pacific Ocean,<sup>[24][25]</sup> which engendered considerable public controversy concerning the effects of man-made sounds on marine mammals.<sup>[26][27][28]</sup>

Tomography has come to be a valuable method of ocean observation,<sup>[29]</sup> exploiting the characteristics of long-range acoustic propagation to obtain synoptic measurements of average ocean temperature or current. Applications have included the measurement of deep-water formation in the Greenland Sea in 1989,<sup>[30]</sup> measurement of ocean tides,<sup>[31] [32]</sup> and the estimation of ocean mesoscale dynamics by combining tomography, satellite altimetry, and in situ data with ocean dynamical models.<sup>[33]</sup> In addition to the decade-long measurements obtained in the North Pacific, acoustic thermometry has been employed to measure temperature changes of the upper layers of the Arctic ocean basins,<sup>[34]</sup> which continues to be an area of active interest.<sup>[35]</sup> Acoustic thermometry was also recently been used to determine changes to global-scale ocean temperatures using data from acoustic pulses sent from one end of the Earth to the other.<sup>[36] [37]</sup>

## Tides and mixing

In recent years Munk has returned to the work on the role of tides in producing mixing in the ocean.<sup>[38]</sup> In a 1966 paper "Abyssal Recipes", Munk was one of the first to quantitatively assess the rate of mixing in the abyssal ocean in maintaining oceanic stratification.<sup>[39]</sup> According to Sandström's theorem (1908), without the occurrence of mixing in the abyssal ocean,

such as may be driven by internal tides, most of the ocean would become cold and stagnant, capped by a thin, warm surface layer.

Munk has also recently focused on the relation between changes in ocean temperature, sea level, and the transfer of mass between continental ice and the ocean.

## Awards

Munk was elected to the National Academy of Sciences in 1956 and to the Royal Society of London in 1976. He has been both a Guggenheim Fellow (three times) and a Fulbright Fellow. He was also named California Scientist of the Year by the California Museum of Science and Industry in 1969. Among the many other awards and honors Munk has received are the Arthur L. Day Medal, from the Geological Society of America in 1965, the Sverdrup Gold Medal of the American Meteorological Society in 1966, the Gold Medal of the Royal Astronomical Society in 1968, the first Maurice Ewing Medal sponsored by the American Geophysical Union and the U.S. Navy in 1976, the Alexander Agassiz Medal of the National Academy of Sciences in 1976, the Captain Robert Dexter Conrad Award from the U.S. Navy in 1978, the National Medal of Science in 1983, the William Bowie Medal of the American Geophysical Union in 1989, the Vetlesen Prize in 1993, the Kyoto Prize in 1999, the first Prince Albert I Medal in 2001, and the Crafoord Prize of the Royal Swedish Academy of Sciences in 2010 "for his pioneering and fundamental contributions to our understanding of ocean circulation, tides and waves, and their role in the Earth's dynamics".

In 1981, Munk became a founding member of the World Cultural Council.<sup>[40]</sup>

Munk gave the 1986 Bakerian Lecture at the Royal Society on the *Acoustic monitoring of ocean gyres*.

In 1993 Munk was the first recipient of the Walter Munk Award given "in Recognition of Distinguished Research in Oceanography Related to Sound and the Sea."<sup>[41]</sup> This award is given jointly by the Oceanography Society, the Office of Naval Research and the US Department of Defense Naval Oceanographic Office.<sup>[41]</sup>

## Books

- W. Munk and G.J.F. MacDonald, *The Rotation of the Earth: A Geophysical Discussion*, Cambridge University Press, 1960, revised 1975. ISBN 0-521-20778-9
- W. Munk, P. Worcester, and C. Wunsch, *Ocean Acoustic Tomography*, Cambridge University Press, 1995. ISBN 0-521-47095-1
- S. Flatté (ed.), R. Dashes, W. H. Munk, K. M. Watson, F. Zachariasen, *Sound Transmission through a Fluctuating Ocean*, Cambridge University Press, 1979. ISBN 978-0-521-21940-2
- H. von Storch and K. Hasselmann, *Seventy Years of Exploration in Oceanography: A Prolonged Weekend Discussion with Walter Munk*, Springer, 2010. ISBN 978-3-642-12086-2

## Documentaries/Films

- *Waves Across the Pacific* (<https://www.youtube.com/watch?v=MX5cKoOm6Pk>) on YouTube (1967) This documentary showcases Munk's research on waves generated by Antarctic storms. The film documents Munk's collaboration as they track storm-driven waves from Antarctica across the Pacific Ocean to Alaska. The film features



Carl XVI Gustaf of Sweden presents the Crafoord-Prize to Munk

scenes of early digital equipment in use in field experiments with Munk's commentary on how unsure they were about using such new technology in remote locations.

- **One Man's Noise: Stories of An Adventurous Oceanographer** (<https://www.youtube.com/watch?v=je3QvqNdHI0>) on **YouTube** (1994) A television program on the work and life of Walter Munk produced by the University of California.
- **Perspectives on Ocean Science: Global Sea Level: An Enigma** (<https://www.youtube.com/watch?v=lks2hh6LGsE>) on **YouTube** (2004) A seminar on global sea level and climate change by Walter Munk. (YouTube link)
- **The Sound of Climate Change** (<http://www.crafoordprize.se/events/crafoorddays2010.4.5ce3bd8012d79a5929580004998.html>) (2010) Munk's Crafoord Prize Lecture
- **Spirit of Discovery** (2017) This documentary showcases Munk as he goes in search of *Mobula munkiana* a species that bears his name. <http://www.spiritofdiscovery.co>

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## External links

- Scripps Institution of Oceanography (<http://scripps.ucsd.edu/>)
- UCSD Institute of Geophysics and Planetary Physics (<http://www.igpp.ucsd.edu/>) (IGPP)
- Biography UCSD (<https://web.archive.org/web/20051216072240/http://scilib.ucsd.edu/sio/archives/siohstry/munk-biog.html>)
- Biography Columbia U. ([http://www.ideo.columbia.edu/vetlesen/recipients/1993/munk\\_bio.html](http://www.ideo.columbia.edu/vetlesen/recipients/1993/munk_bio.html))
- Oral History interview transcript with Walter Munk 30 June 1986, American Institute of Physics, Niels Bohr Library and Archives (<https://www.aip.org/history-programs/niels-bohr-library/oral-histories/4790>)
- Kyoto Prize ([https://web.archive.org/web/20071023085326/http://www.inamori-f.or.jp/laureates/k15\\_b\\_walter/prf\\_e.html](https://web.archive.org/web/20071023085326/http://www.inamori-f.or.jp/laureates/k15_b_walter/prf_e.html))
- The Heard Island Feasibility Test (<http://faculty.washington.edu/dushaw/heard/index.shtml>)

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