

Press release

March 31, 2026

In the Climate Change and Environmental Sciences category

## The Frontiers of Knowledge Award goes to Carl Wunsch for his foundational contributions to pioneering studies that revealed the impact of global warming on the world's oceans

- **Wunsch developed innovative methods to faithfully observe and quantify the state of the oceans under a changing climate**, and led groundbreaking scientific projects to measure and analyze the effects of global warming, using newly available technologies like satellite images taken from space
- **The awardee's research "has been instrumental in the design of ongoing global ocean observation programs**, which underpin current estimates of an alarming increase in ocean heat content in response to increasing greenhouse gases," said the committee in its citation
- **His work set the stage for later studies that confirmed the risk of sea-level rise**, due to the polar ice melt, along with the growing intensity of extreme weather events like heat waves, storms, and floods driven by rising temperatures and the accumulation of thermal energy in the ocean
- **Wunsch's achievements "emphasize the importance of international cooperation to solve global problems,"** the committee said in closing. They also "epitomize the power of collaborative science to answer fundamental questions on the future trajectory of the climate system, and its consequences for life on the planet"

The BBVA Foundation Frontiers of Knowledge Award in the Climate Change and Environmental Sciences category has gone in this 18th edition to Carl Wunsch (Massachusetts Institute of Technology) for his foundational contributions to studies that revealed the impact of global warming on the world's oceans.

The awardee researcher "had the early insight that the ocean plays a central role in regulating Earth's climate," reads the Frontiers citation. Guided by this insight, he developed the innovative methods that allow scientists to precisely quantify the state of the ocean under a changing

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climate, and, in doing so, “demonstrated the need for a global ocean observing system,” able to integrate observations of a diverse nature, made from space or from inside the ocean.

Wunsch himself would lead pioneering scientific projects aimed at measuring and analyzing the effects of global warming using newly available technologies like satellite images taken from space. His work, as such, “has been instrumental in the design of ongoing global ocean observation programs, which underpin current estimates of an alarming increase in ocean heat content in response to increasing greenhouse gases.”

His approach, said the committee, “emphasizes the importance of international cooperation to solve global problems,” as instantiated by the various international projects he himself instigated and led. It also “epitomizes the power of collaborative science to answer fundamental questions on the future trajectory of the climate system, and its consequences for life on the planet.”

“Before Professor Wunsch’s work, there wasn’t any kind of coherent global ocean observation system,” explains committee secretary Carlos Duarte, holder of the Tarek Ahmed Juffali Research Chair in Red Sea Ecology at King Abdullah University of Science and Technology (Saudi Arabia). “Thanks to analytical methods of his devising and the global-scale oceanographic observation system he pioneered, we have been able to obtain predictions of changes in ocean dynamics, the rate of ice melt in the polar oceans, sea-level rise, and how the ocean’s heat content is changing and increasing – with current estimates that are truly alarming as to the energy accumulated, which is driving extreme events like the torrential rains that have repeatedly hit the Iberian Peninsula.”

“The ocean is one of the most important components of the Earth’s climate system, but it is very difficult to know what is going on beneath its surface. What Prof. Wunsch accomplished was to devise measurement systems, very ingenious ones, that give us a better understanding of how the ocean circulation works and how it takes up heat in the climate system,” adds fellow committee member Kerry Emanuel, Cecil & Ida Green Professor of Atmospheric Science at MIT. “His contributions have been indispensable in quantifying the increases in ocean temperature and accumulation of thermal energy linked to greenhouse gas emissions, a problem that will manifest in rising sea levels and other problems such as increased incidence of heat waves, drought, wildfires and floods.”

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## The birth of a “radically different” strategy for studying the ocean

Carl Wunsch initially studied mathematics, earning a degree in the subject at MIT in 1962, but before long found himself increasingly drawn to ocean exploration. This change of heart owed partly to the influence of Henry Stommel, a charismatic MIT faculty member and an authority in the physical oceanography field who would end up supervising his PhD thesis, and partly to the promise of adventure held out by the discipline, far from offices and lecture halls: “One of the great attractions of physical oceanography at the time is that you got to go to sea on ships, which was a wonderful change from sitting in front of a computer or a pad of paper,” remarked the new laureate in an interview shortly after hearing of the award.

At that point in his studies, Wunsch was spending long months carrying out measurements from onboard research vessels; a fairly rudimentary way of working that had two major drawbacks: its expense and its slowness. “It costs a lot of money to take 30 to 50 people to sea for weeks at a time, and it’s also a very lengthy process. This had led to a misconception about how the ocean works, because the picture built up was of this very slowly changing, almost kind of geological structure.”

All this changed, however, in the 1970s, when technological advances – particularly space-based satellite observations and improvements in data processing capabilities – began to transform our image of the ocean: “We learned, as some had long suspected, that the ocean was turbulent like the atmosphere.” It was then that Wunsch came to realize, ever more clearly, that oceanography “had a serious observational problem” – it was simply not possible to keep ships in one place for long enough to track the constant changes taking place in the oceanic climate.

This dearth of observations and reliable data in his chosen field was brought home to him forcibly when he had the chance to participate as co-author in the pioneering 1979 study organized by the U.S. National Academy of Sciences on the global impact of climate change: “It was the first attempt to conduct a serious study of the effects of climate change caused by rising CO<sub>2</sub> levels, and it became clear that we oceanographers had very little to contribute. When asked how much of the carbon that was going into the atmosphere would go into the ocean or the amount of heat that would end up there, the truth was that we simply didn’t know because we lacked the observational basis.”

Wunsch decided there and then that oceanography required “a radically different approach.” To properly assess the state of the oceans and the impacts of climate change on the marine environment, what was needed was a new observation system and analytical methodology that

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would allow for the calculation, on a planetary scale, of how ocean heat content and thermal energy were changing under global warming.

His response was to pour his energies into instigating a series of major international projects to collect ocean data from around the globe, while developing mathematical and analytical tools that would support the use of these observations to verify the temperature increase and accumulation of heat caused by global warming.

### **Pioneering missions that revolutionized oceanographic observation**

Firstly, in 1990, Wunsch led the organization of the World Ocean Circulation Experiment (WOCE), conceived as an observation system that would offer a comprehensive map of heat flux linked to ocean circulation and its variability in the context of climate change, with a particular focus on gathering data from the Southern Ocean, which had only been sparsely sampled at that time.

The data collected by WOCE – a 12-year project working with readings from satellites and buoys equipped with sensors to measure temperature, salinity, and other key parameters – enabled better calibrated climate models, laying the groundwork for a global understanding of ocean circulation, while spurring development of new tools and approaches for sampling at sub-oceanic levels.

“In the early 1980s, the meteorological community was running what became known as the World Climate Research Programme, an international program whose goal was to improve weather forecasting,” Wunsch relates. “It was clear that, to improve the prediction of climate, we first had to understand it, and there were many meteorologists who recognized that, to do so, we had to understand the ocean.” With this goal in mind, he proposed a mission that had until lately seemed impossible: the time had come to observe the oceans at a global scale, using precision instruments.

Technology had by then advanced enough to bring the dream within reach: “Before that, I would have been laughed out of the room,” he admits, thinking back to the days when “ships took a month to cross the Atlantic and you couldn’t cross the Pacific without stopping over at some port.” Now, however, these limitations could increasingly be overcome. Wunsch was determined to expand the scope of oceanographic research, with his sights set on what would become known as satellite altimetry.

“It had been known for 80 years that when the ocean flowed, the surface tilted so that if the flow was clockwise, as it is in the Sargasso Sea in the Atlantic, there would be a high on the right as the

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fluid went around it, the same way as in the atmosphere,” the oceanographer explains.

In theory, then, it was already known that much of the near-surface ocean flow manifests as undulations and fluctuations in sea surface height, but that their magnitude was confined to a range of tens of centimeters – so small a scale that for many of Wunsch’s scientific colleagues “it was not conceivable that one could measure it.”

Working closely with engineers, he was able to get past this restrictive view: “With the right satellite and radar, we believed, we could measure the highs and lows of the sea surface to an accuracy of a few centimeters.”

The proof would come in 1992 with the launch of the high-precision altimeter built under the TOPEX/Poseidon project, in which Wunsch had played a leading role. A Franco-American mission, its purpose was to make continuous measurements of the dynamic topography of the surface of the world ocean using space-based altimetric radars.

“TOPEX-Poseidon made it possible to calculate changes in the ocean’s heat content based on changes in its height, since a warmer ocean is less dense so occupies a larger volume for the same mass,” explains Carlos Duarte, referring to the project’s application in tracking variations in heat.

Originally designed to run for three years, the mission was so successful that it would go on feeding data to the scientific community for a further ten years. This extended timeframe allowed Wunsch and his colleagues to monitor the effects of ocean currents on climate change and produce the first global map of seasonal changes in ocean currents.

From 1998 until today, Wunsch’s scientific vision and methodological insights found their most notable application in the Argo project, which combines satellite altimetry with measurements taken by a global fleet of robotic probes made up of almost 4,000 free-drifting floats that take continuous, simultaneous measurements of ocean temperature, salinity and currents down to a depth of 2,000 meters. The data they collect is transmitted via satellite, and then distributed to generate accurate estimates of the global increase in ocean temperature.

### **High levels of risk due to sea-level rise and extreme weather events**

For Wunsch, the data collected in recent decades through the international oceanographic observation projects drawing on his work offer clear and troubling insights into the risk posed by the impacts of global warming on our oceans.

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“We know that sea level is rising on the global average,” he relates, “and in some places more rapidly than others.” What remains to be determined is whether the melting process will accelerate over the next 50 years, which would bring “a catastrophic change,” or whether it will happen more gradually over 1,000 years, “allowing people to adjust in some way.” In any case, there is no doubting the severity of the threat.

Another clear warning that emerges from oceanographic observations is that the heat accumulating in the world’s oceans is driving up the risk of extreme weather events, like heat waves, floods and torrential rains: “What is going on in the climate system is that as it heats up, it becomes more energetic. It’s like a pendulum swinging back and forth, where you expect to see extremes. But if you add more energy to the pendulum, these extremes get bigger. The more energetic the ocean is, the more extreme events you can expect.”

Faced with a challenge of this magnitude, Wunsch emphasizes the importance of global scientific cooperation among countries, which he has championed throughout his career, and considers “absolutely essential” to confront global warming: “Climate is a global phenomenon, and there’s no way of understanding what’s changing and what could change for better or worse without international cooperation.”

## Laureate bio notes

**Carl Wunsch** (Brooklyn, New York, United States, 1941) earned a bachelor’s degree in mathematics (1962) and a PhD in geophysics (1966) from the Massachusetts Institute of Technology. His academic and research career has largely been spent at this institution, where he began as a professor of Oceanography in 1967, served as chair of the Department of Earth and Planetary Sciences from 1977 to 1981, and is now Cecil & Ida Green Professor Emeritus of Physical Oceanography. Wunsch is also an Associate in the Department of Earth and Planetary Sciences at Harvard University, having worked there in a visiting capacity for the previous ten years. He has also held visiting positions at the universities of Washington and Princeton, the California Institute of Technology, the universities of Oxford and Cambridge in the United Kingdom, and, in France, the Space Geodesy Research Group (GRGS), a public research consortium. Author or co-author of approximately 300 published papers and five books, he has chaired the Ocean Studies Board of the National Academy of Sciences and NASA’s Altimetry Science Working Group (TOPEX), as well as the International Steering Group of the World Ocean Circulation Experiment (WOCE) under the World Climate Research Programme.

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## Nominators

A total of 112 nominations were received in this edition, comprising 124 candidates. The awardee researcher was nominated by **D. James Baker**, former Under Secretary of Commerce and former Administrator of the National Oceanic and Atmospheric Administration (United States); **Anny Cazenave**, Senior Scientist at the Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (France) and recipient of the 2018 Frontiers of Knowledge Award in Climate Change and Environmental Sciences; **Baylor Fox-Kemper**, professor in the Department of Earth, Environmental and Planetary Sciences at Brown University (United States); **Lee-Lueng Fu**, Senior Research Scientist in the Jet Propulsion Laboratory at the California Institute of Technology (United States); **Patrick Heimbach**, professor in the Department of Earth and Planetary Sciences at the University of Texas at Austin (United States); **Peter Huybers**, professor in the Department of Earth and Planetary Sciences at Harvard University (United States); **Syukuro Manabe**, Senior Meteorologist on the Program in Atmospheric and Oceanic Science at Princeton University and at the National Oceanic and Atmospheric Administration (United States), and recipient of the 2016 Frontiers of Knowledge Award in Climate Change and Environmental Sciences, and the 2021 Nobel Prize in Physics; **Jochem Marotzke**, Director of the Max Planck Institute for Meteorology (Germany); **Trevor J. McDougall**, Emeritus Scientia Professor of Ocean Physics at the University of New South Wales (Australia) and president of the International Association for the Physical Sciences of the Ocean; **Marcia K. McNutt**, President of the National Academy of Sciences (United States); **Jean-Francois Minster**, former Chairman of the Board of the French Research Institute for Exploitation of the Sea (IFREMER); **Joseph Pedlosky**, Senior Scientist Emeritus at the Woods Hole Oceanographic Institution (United States); **Detlef Stammer**, Chair of the Joint Scientific Committee of the World Climate Research Programme (Switzerland); **Hans von Storch**, Director Emeritus of the Institute for Coastal Systems at Helmholtz-Zentrum Hereon (Germany); **Byron Tapley**, Clare Cockrell Williams Centennial Chair Emeritus in the Department of Aerospace Engineering at the University of Texas at Austin (United States); and **Eli Tziperman**, Pamela and Vaco McCoy, Jr. Professor of Oceanography and Applied Physics in the Department of Earth and Planetary Sciences at Harvard University (United States).

## Climate Change and Environmental Sciences committee and evaluation support panel

The committee in this category was chaired by **Bjorn Stevens**, Director of the Max Planck Institute for Meteorology (Germany), with **Carlos Duarte**, holder of the Tarek Ahmed Juffali

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Research Chair in Red Sea Ecology at King Abdullah University of Science and Technology (Saudi Arabia) and Frontiers of Knowledge laureate in Climate Change and Environmental Sciences, acting as secretary.

Remaining members were **Emily Bernhardt**, James B. Duke Distinguished Professor and **Chair of the Department of Biology at Duke University (United States)**; **Miquel Canals**, Director of the Sustainable Blue Economy Chair at the University of Barcelona (Spain); **Kerry Emanuel**, Cecil & Ida Green Professor post tenure of Atmospheric Science at the Massachusetts Institute of Technology (United States) and Frontiers of Knowledge laureate in Climate Change and Environmental Sciences; **José Manuel Gutiérrez**, Research Professor at the Institute of Physics of Cantabria (IFCA), CSIC-University of Cantabria (Spain), **Pedro Jordano**, Research Professor in the Department of Integrative Ecology at Doñana Biological Station, CSIC (Spain); **Rik Leemans**, Emeritus Professor in Environmental Systems Analysis at Wageningen University & Research (The Netherlands); **Ning Lin**, Professor of Civil and Environmental Engineering at Princeton University (United States); and **Edward S. Rubin**, Alumni Chair Professor of Environmental Engineering and Science Emeritus at Carnegie Mellon University (United States).

The **CSIC evaluation support panel** charged with nominee pre-assessment was coordinated by **Elena Cartea**, Deputy Vice-President of Scientific-Technical Areas at the Spanish National Research Council (CSIC) and **Teresa Moreno Pérez**, Deputy Coordinator of the Life Global Area and Research Professor at the Institute of Environmental Assessment and Water Research (IDAEA, CSIC); and formed by **Josep M. Gasol Piqué**, Research Professor at the Institute of Marine Sciences (ICM, CSIC); **Ernesto Igartua Arregui**, Deputy Coordinator of the Life Global Area and Scientific Researcher at the Aula Dei Experimental Station (EEAD, CSIC); **Ana M. Traveset Vilagines**, Research Professor at the Mediterranean Institute for Advanced Studies (IMEDEA, CSIC-UIB); and **Sergio Vicente Serrano**, Research Professor at the Pyrenean Institute of Ecology (IPE, CSIC).

## About the BBVA Foundation Frontiers of Knowledge Awards

The BBVA Foundation centers its activity on the promotion of world-class scientific research and cultural creation, and its transmission to society, along with the recognition of talent through families of awards organized alone or in conjunction with scientific societies and the Spanish National Research Council (CSIC).

The BBVA Foundation Frontiers of Knowledge Awards, funded with 400,000 euros in each of

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their eight categories, recognize and reward contributions of singular impact in basic sciences, biomedicine, environmental sciences and climate change, social sciences, economics, the humanities and music. The goal of the awards, established in 2008, is to celebrate and promote the value of knowledge as a global public good, the best tool at our command to confront the defining challenges of our time and expand individual worldviews. Their eight categories are congruent with the knowledge map of the 21st century.

A total of 34 Frontiers of Knowledge laureates in the 17 editions held to date have gone on to win the Nobel Prize.

The BBVA Foundation is partnered in these awards by the Spanish National Research Council (CSIC), the country's premier public research organization. CSIC appoints evaluation support panels made up of leading experts in the corresponding knowledge area, who are charged with undertaking an initial assessment of candidates and drawing up a reasoned shortlist for the consideration of the award committees. CSIC is also responsible for designating each committee's chair across the eight prize categories and participates in the selection of remaining members, helping to ensure objectivity in the recognition of those who have achieved particularly significant advances in science and in music. The presidency of CSIC also has a prominent role in the awards ceremony held each year in Bilbao, the permanent home of the BBVA Foundation Frontiers of Knowledge Awards.

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