

## Oeschger

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Joel B. Hagen

**OESCHGER, HANS** (*b.* Ottenbach, Zürich, Switzerland, 2 April 1927; *d.* Bern, 25 December 1998), *environmental physics, radioactive tracers, climate reconstruction, ice core analysis, carbon cycle modeling, rapid climate change events, earth science, climate change.*

Oeschger was a pioneer in Earth system science based on experimental physics. Working at the Physics Institute of the University of Bern (Switzerland), he developed a counter for low levels of natural radioactivity and thus enabled the use of a number of new environmental tracers. He employed polar ice from Greenland and Antarctica as an archive of information on past changes of the atmosphere's content of greenhouse gases and, with his team, developed various devices measuring their concentrations in small samples. With his colleague Willy Dansgaard, he identified in the Greenland ice cores a series of abrupt climate changes during the last ice age, which have become commonly known as Dansgaard-Oeschger events. Oeschger also developed the first model of the global carbon cycle, which he used to estimate the consequences of anthropogenic (human-produced) emissions of greenhouse gases.

Oeschger grew up in Zürich with a brother and a sister. He married Dori Häuptli in 1955. In 1957 their twin daughters were born.

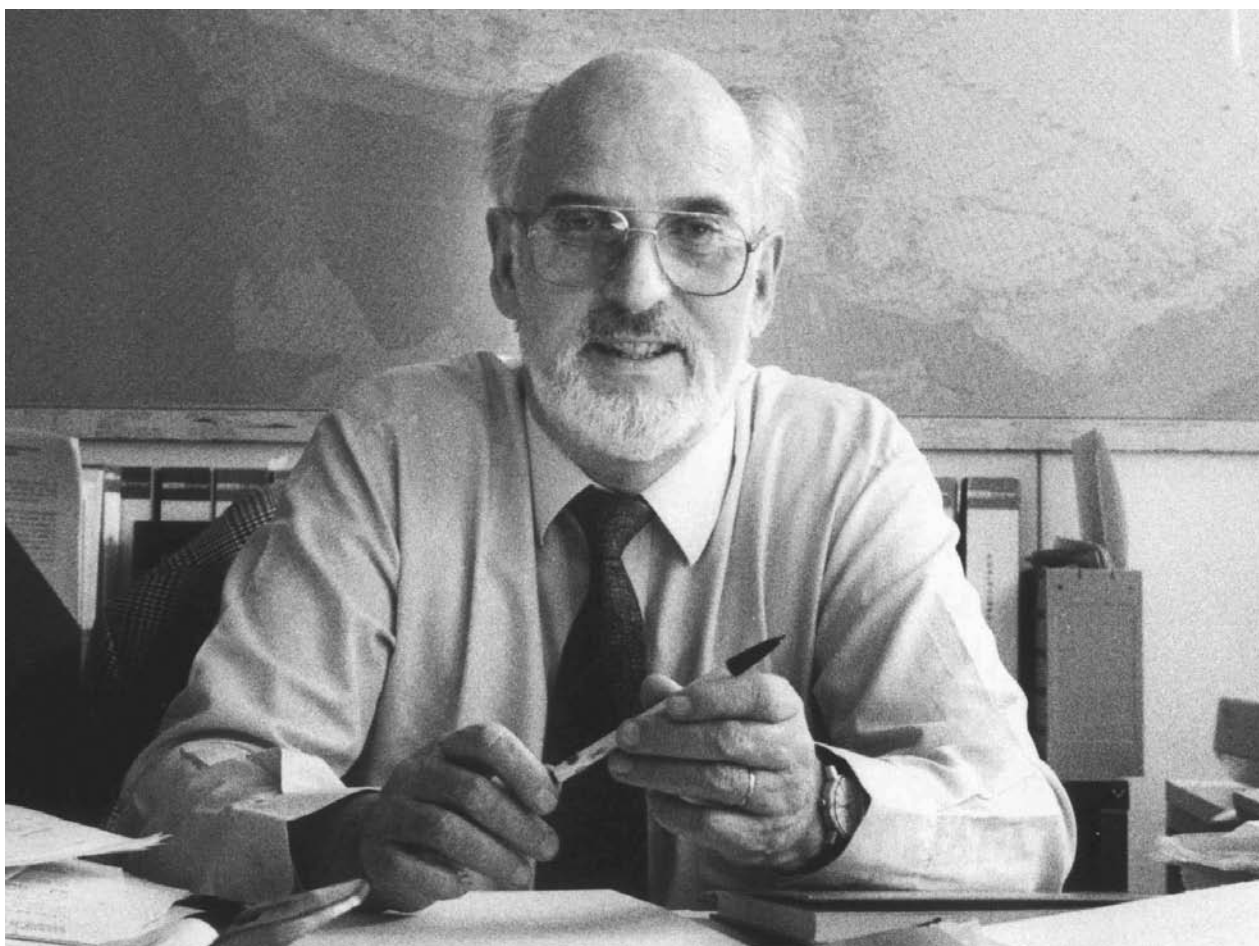
Oeschger studied physics at the Swiss Federal Institute of Technology (ETH Zürich) where he obtained his

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diploma in 1951. His primary motivation to study physics was the hope to find "firm ground in the fundamental equations of physics" (Response of Oeschger, 14 May 1998 on the occasion of his departure from the board of ETH) to which complex processes in nature can seemingly be reduced. He then moved to the University of Bern to take up PhD work under the supervision of Friedrich Georg Houtermans, a nuclear physicist trained by James Franck in the legendary physics community at the University of Göttingen (Germany). Houtermans made fundamental contributions to the understanding of energy conversion in stars and the determination of the age of Earth, but he also inspired many young physicists during his professorship at the University of Bern: "Oeschger wanted to become a musician. However, since I [Houtermans] do physics much like an artist, he [Oeschger] now feels quite comfortable in physics" (from obituary speech by daughter Ursula Oeschger, 30 December 1998, Bern).

**Experimental Physics: Basis of Environmental Science.** While working toward his PhD from 1951 to 1955, Hans Oeschger's task was to set up the first radiocarbon laboratory in Switzerland. Determination of the content of radiocarbon ( $^{14}\text{C}$ ) in organic material was a novel method for dating. As a physicist he was not content to simply implement established technology. Instead he set out to develop a new device with which unprecedented levels of low radioactivity could be measured for the first time. This device, described in his dissertation and now commonly referred to as the Oeschger counter, counted electrons emitted during the decay of the radioactive material. It had a lower background than any other available instrument, owing to a clever anticoincidence technique that dismissed counts that were not caused by the decaying sample. It is still used in the early twenty-first century for conventional radiocarbon dating.

This increased sensitivity was ideally suited for measuring samples with very low concentrations of  $^{14}\text{C}$ . For example, water contains dissolved carbon originating from earlier exchange with the atmosphere and therefore also carries the carbon-14 signature of the atmosphere. Separated from contact with the atmosphere, the carbon-14 decays and so offers a means to measure the apparent age of ocean water. In 1959 Oeschger started a collaboration with Roger Revelle and Hans Suess, and spent three months at the Scripps Institution of Oceanography, La Jolla, California. He used his new counter to measure  $^{14}\text{C}$  of waters from the deep Pacific Ocean and reported the results at the First International Oceanographic Congress held in New York in 1959. Oeschger's results provided most of the fresh data used to determine for the first time that the apparent age of deep water from the Pacific



*Hans Oeschger.* AP IMAGES.

Ocean was about 1,500 years. This was reported by George Bien, Norris Rakestraw, and Suess in 1960.

The Oeschger counter enabled the team at the University of Bern to enlarge significantly the palette of natural tracers whose radioisotopes could be measured. In addition to carbon-14, also hydrogen-3, argon-37, argon-39, and krypton-85 were measured with this technique: Measurements were performed in various environments such as the atmosphere, groundwater, ocean water and, eventually, ice from the polar ice sheets. Oeschger reported this important progress in environmental analytics in a series of papers with Houtermans and with his PhD student Hugo Loosli in the 1960s.

In 1963 Oeschger was promoted to associate professor at the University of Bern, and became the head of the Laboratory of Low-Level Counting and Nuclear Geophysics. He embarked on a vigorous program of developing new analytical techniques of measuring weak radioactivity in the environment. Oeschger and “The Bern Team,” as he called his group, started to apply these

methods to a broad range of fields such as oceanography, hydrology, limnology, and dendrochronology, as well as Quaternary geology. During this time, Oeschger realized that the collaboration of scientists across disciplinary boundaries was crucial if the processes governing the Earth system are to be quantitatively understood. In fact, he was among the first scientists of the “hard-core” physics community to address environmental problems and collaborate with chemists, biologists, geographers, and geologists, while still remaining deeply involved, and internationally respected, in disciplinary research in nuclear geophysics. Oeschger was promoted to full professor at the University of Bern in 1971, and was granted emeritus status in 1992.

**Polar Ice as a Climate Archive.** The tritium fallout from atmospheric nuclear testing in the early 1960s provided a test bed for the application of the new analytical techniques developed in Bern. With the ice stream of the Great Aletsch Glacier not far from Bern, tritium ( $^3\text{H}^1\text{HO}$ )

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was first measured in the surface layers of the firn (granular snow) on Jungfrauoch in 1962. This technique was then applied to ice samples from Greenland as reported in 1963. The next goal was to date Greenland ice using radiocarbon. This marked the start of a long and fruitful collaboration with Chester C. Langway (then at Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire); their report appeared in *Nature* in 1965. In spring 1964, Oeschger visited Greenland for the first time, and in summer 1967 he led a group of scientists during the Expédition Glaciologique Internationale au Groenlande (EGIG). With Danish and American colleagues they melted large quantities of ice for radiocarbon dating. Oeschger also participated in fieldwork at Byrd Station (Antarctica) in 1969.

With access to very old, pristine ice from Greenland and Antarctica, Oeschger and his team at the Physics Institute of the University of Bern continued the effort to build better analytical techniques and equipment suitable for ice samples, in particular gas measurements. The potential of this archive was recognized by P. F. Scholander and colleagues and L. K. Coachman and colleagues in 1956. One of the new analytical techniques was laser absorption spectroscopy, which permitted the determination of concentrations of substances and their isotopes in spite of very small sample sizes. This was described by Bernhard Lehmann, one of Oeschger's PhD students, in 1977. The idea is to use the fundamental physical property of a gas of absorbing photons at specific wavelengths and reemitting them with a delay in a random direction.

This quantum mechanical effect associated with the vibration and rotation of gas molecules has profound implications in Earth system science. For example, water and carbon dioxide (CO<sub>2</sub>), and many other gases in the atmosphere, change the radiation balance and are responsible for the greenhouse effect of Earth. In the laboratory, the same effect can be utilized to measure with high precision the concentration of these gases. The absorption of a tuned laser beam shining through the air sample is proportional to the concentration of the absorbing gas. By tuning the wavelength to a value typical for an individual constituent of the gas mixture, concentrations of different gases and even different isotopes can be measured.

A special challenge was the construction of suitable extraction techniques that liberated the air from the enclosing ice matrix in samples from deep ice cores. The successful development was the result of a close collaboration with students as well as skilled technical personnel and long-term associates, and the excellent and dedicated workshop of the Physics Institute of the University of Bern.

This led to arguably the most important contribution of Oeschger and his team in climate research. In 1982 his PhD student Albrecht Neftel published evidence of a sub-

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stantial reduction of atmospheric concentrations of CO<sub>2</sub> during the last ice age. This study demonstrated for the first time that CO<sub>2</sub> was an important, if not determining, factor for the Earth system to make a transition between ice ages and warm phases. Methane, the third most important greenhouse gas after water vapor and CO<sub>2</sub>, showed an even more dramatic increase since preindustrial times and the last ice age. These results were published by Bernhard Stauffer, a former PhD student and later colleague of Hans Oeschger at the University of Bern, in *Science* (1985) and *Nature* (1988).

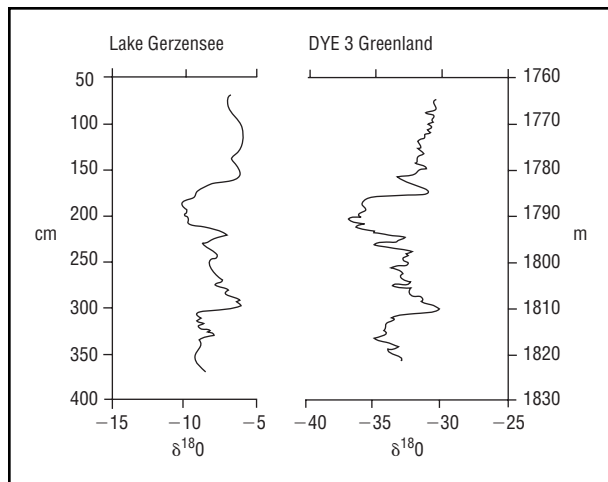
**From Past Changes to Current Concerns.** Hans Oeschger was not content with developing experimental devices for environmental measurements, but complemented these achievements with original research into the understanding of various processes in the Earth system. This required quantitative interpretation of the data, and hence models needed to be formulated. In 1975 Oeschger devised the first model of the global carbon cycle with a realistic representation of the relevant ocean processes. The model consisted of a small number of boxes representing different inventories of carbon in the atmosphere, the oceans, and various compartments of the terrestrial biosphere. Although trained as a physicist and familiar with the canonical physical approach of every issue starting from, or reducing to, the fundamental equations of physics, Oeschger realized that the complexity of the Earth system required a radically different yet complementary approach.

With this strategy in mind, he made the necessary simplifications toward one of the first models of the Earth system, which he and his PhD student Uli Siegenthaler then used to estimate the increase of atmospheric CO<sub>2</sub> in response to anthropogenic emissions. They reported their findings in *Science* in 1978. The model became a classic and is used, in variants, in international assessments of climate change by the Intergovernmental Panel on Climate Change. It was also this research that brought Oeschger to the conclusion that scientists, through their insights, have a wider responsibility: "The worst for me," he declared, "would be if there were serious changes in the next five to ten years and we scientists are helpless and did not have the courage to point out these dangerous developments early on" (quote from Global Alliance for Incinerator Alternatives [1995, vol. 4 (1), p. 35]), Oeschger contributed to the first assessment report of the Intergovernmental Panel of Climate Change, which appeared in 1990.

**Abrupt Climate Changes: Dansgaard-Oeschger Events.** Chester C. Langway (United States), Willy Dansgaard (Denmark), and Hans Oeschger initiated the trinational Greenland Ice Sheet Program (GISP) in 1971 which, after

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**Figure 1.** Image representing the abrupt changes around 12,000 years ago measured in the isotopic composition oxygen of the water molecule in the ice drilled at Dye 3 (Greenland) and in the oxygen molecule of carbonate in lake sediments from Gerzensee (Switzerland) were juxtaposed and thus suggested, for the first time, the large-scale significance of abrupt climate changes identified in Greenland ice cores.

drilling various shallow cores, culminated in the deep drilling at Dye 3 (65°11' N, 43°49' W) reaching a depth of 2,037 meters. This deep ice core yielded a wealth of new information about the climate system and its variability during the last 150,000 years. Langway, Oeschger, and Dansgaard, and Oeschger and Langway coedited two books in 1985 and 1989, which strongly influenced ice core science for the coming decades.

One of the surprise findings of the GISP project was reported by Dansgaard and Oeschger in two articles in 1984. They discussed a series of abrupt shifts in the isotope records analyzed in the Greenland ice from Dye 3. Oeschger compared the last of these isotopic shifts around 10,000 BCE to a similar shift found in the carbonate isotope record of Lake Gerzensee, a small proglacial lake near Bern. He concluded correctly that the shifts found in the Greenland ice core therefore represented a much larger-scale climate signal. This early insight has been confirmed in many paleoclimatic archives since then, and these abrupt warming events—twenty-six are recorded in Greenland during the last ice age as reported by the NorthGRIP members in *Nature* in 2004—are commonly referred to as Dansgaard-Oeschger events.

The potential role of changes in ocean circulation for climate jumps was outlined mathematically by oceanographer Henry Stommel as early as 1961. Both Dansgaard and Oeschger were aware of earlier work on marine sediments by William Ruddiman (1981) that showed that the geographical occurrence of cold-loving, surface-dwelling

foraminifera in the North Atlantic changed substantially and rapidly in latitude around the same time. While Dansgaard and colleagues in their 1984 article invoked an atmospheric feedback mechanism proposed by Hermann Flohn in 1982, Oeschger and colleagues suggested a complementary hypothesis in 1984, that the ocean circulation might be responsible for these large-scale and rapid climate swings. This was motivated by indications of changes in the atmospheric CO<sub>2</sub> concentrations that were measured on the same ice core and thought to be associated with these rapid climatic changes. They argued that the warm phases are characterized by a rapid turnover rate of the North Atlantic Ocean creating high levels of CO<sub>2</sub>, whereas during the ice ages this turnover rate was slow and hence leading to lower concentrations of CO<sub>2</sub>.

In a review article that appeared in 1985 Oeschger used the physical analogy of a bistable system to explain abrupt climate change: Triggered by small perturbations, the ocean circulation might switch from one circulation mode to another. Based on these insights, Oeschger was one of the first to point out that the anthropogenic increase of CO<sub>2</sub> could represent such a perturbation. As acknowledged by Wallace Broecker in 1997, this paved the way for more than two decades of intensive research on abrupt climate change (Alley, et al. 2002).

**Carrying Global-Change Research Further.** Hans Oeschger was an experimental physicist by training and therefore his primary mission was to build devices that could probe the Earth system. His challenging suggestions to students and collaborators would often be disguised in the gentle and informal Swiss-German phrase “Das söttest mir doch chöne mässe” (we ought to be able to measure this), words that on many occasions marked the beginning of a novel method to quantify environmental processes.

His scientific achievements were widely honored. He received the Harold Urey Medal (1987), the Seligman Crystal (1989), the Marcel-Benoist Prize (1991), the Tyler Prize for Environmental Achievement (1996), and the Revelle Medal of the American Geophysical Union (1997). He was a member of the Leopoldina, the Academia Europaea, and a foreign member of the U.S. National Academy of Sciences.

After his formal retirement in 1992, he became active in international research coordination and cofounded PAGES, Past Global Changes, a core project of the International Geosphere-Biosphere Programme with its project office in Bern. Oeschger’s vision for this initiative was to bring together all science disciplines concerned with the study of the Earth system and its past changes. Thanks to such efforts, paleoclimatology has transformed from a descriptive field into a mature quantitative science in which changes of environmental conditions can be given

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numbers and units. This is the basis of a scientific investigation of the full dynamics of the Earth system and its possible responses to anthropogenic disturbance. These results are of immediate value, but the approach as such may well have broader significance for society: "Real progress in this field will make it possible for society to act based on foresight. The anticipated climate change is only one of the great problems with which society is faced; the thorough way climate change is assessed by the scientific community may serve as an example for addressing other grand challenges" ("Oeschger Receives Revelle Medal," *EOS—Transactions of the American Geophysical Union*, 79 [5], 60–63).

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Thomas Stocker

## OKEN (OR OKENFUSS), LORENZ

(b. Bohlsbach bei Offenburg, Baden, Germany, 1 August 1779; d. Zürich, Switzerland, 11 August 1851), *natural science, philosophy, scientific congresses, science journals, science periodicals*. For the original article on Oken see *DSB*, vol. 10.

This postscript gives new insights into Oken's contribution to science during the first half of the nineteenth century. Historical studies since the 1970s show Oken's continued influence upon the professionalization of science through "the Gesellschaft Deutscher Naturforscher und Ärzte" up to contemporary achievements recorded by Heinrich Schipperges and Dietrich von Engelhardt (1987).

Much more research on romanticism, its relationship to naturphilosophie and science illuminates Oken's transitional role in the integration of institutional science: from Isaiah Berlin's (1999) *Roots of Romanticism* to Andrew Cunningham's and Nicholas Jardine's (1990) *Romanticism and the Sciences*, to insights by Dietrich von Engelhardt, from 1990–1999, notably in English translation "Historical Consciousness in the German Romantic Naturforschung" (1990), and Wolfgang Pross's "Lorenz Oken—Naturforschung zwischen Naturphilosophie und Naturwissenschaft" (1991).

Professional and institutional issues are addressed by Wolfgang Schirmacher (1996) and Elinor Shaffer (1990) showing that education for Oken included science, the history of science, and the professionalization of science through textbooks, notably authored by Oken's *Lehrbuch der Naturphilosophie* (1809, 1843) and *Naturgeschichte für Schüler* (1821). The role of popular science was assured by Oken's encyclopedic *Allgemeine Naturgeschichte für alle Stände* (1839–1842) and through the popular journal *Isis* (1818–1848), confirmed by Dietrich von Engelhardt's 1999 encompassing study *Medizinhistoriographie im Zeitalter der Romantik—Eine Wissenschaft Emanzipiert Sich: die Medizinhistoriographie von der Aufklärung bis zur Postmoderne*.

A study at the University of Jena under the directorship of Dr. Olaf Breidbach sheds light on Oken's political persona. The "sonderdruck" (special publication) with Hans-Joachim Fliedner chronicles Oken's political involvement during the 1817 "burschenschaften" demonstrations in *Lorenz Oken (1779–1851) ein Politischer Naturphilosoph*.

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**Oken and Naturphilosophie.** Oken embraced romantic science and his worldview was shaped by German romanticism and its philosophy of nature, known as Naturphilosophie (Engelhardt, 1999). Oken studied medicine at Freiburg University and natural history at the Universities of Würzburg and Göttingen. In 1802 he conceptualized the *Abriss der Naturphilosophie* summary and published his *System der Naturphilosophie* the following year. His 1805 *Die Zeugung* (Generation) merited recognition by the followers of Naturphilosophie, and notably by Friedrich Schelling who recommended him for a professorial position at Jena.

Similar to Fichte, Oken erected a total system of nature, encompassing philosophy of nature, science, ethics, and spirit. Fichte's 1806 *Addresses to the German Nation* channeled Oken into employing old-German language in order to revitalize scientific expressions and to avoid French usage in the historical context of the Napoleonic era. Oken embraced Schelling's transcendental philosophy briefly, for example, Schelling's two seminal works: *Ersten Entwurf eines Systems der Naturphilosophie* of 1799, and *Die Weltseele* of 1799–1800, but later, during his Jena years, Oken distanced himself from metaphysical speculations. Johann Fichte's *Wissenschaftslehre* and Schelling's transcendental *Idealphilosophie*, exploring a total system of nature that extended philosophical principles into the physical sciences using mathematical elements of *mathesis* as well as empirical observations, and ordering aspects of nature as stages of a comprehensive metamorphosis. With mathesis as an integral part of Naturphilosophie Oken sought to combine reflection with experiment—through algebraic formulation—aimed at achieving a balanced relationship between knowledge and experience. The schema of Oken's system of naturphilosophie encompassed algebraic + 0—defining the equilibrium he named "metaebene" whereby a synthesis of a new intellectual category of "totalität" (totality) was achieved.

Oken structured a unique classification of animal classes into five major groups according to their sense-organs in *Grundriss der Naturphilosophie*, effectively transforming the Linnaean system. In *Die Zeugung* Oken postulated that life began on the seashore as Urschleim (primal mucous plasm) of "infusoria," cells whose agglomerations and combinations formed into organisms (Engelhardt, 1997). Published in his *Beiträge*, Oken's embryological experiments in 1806, assisted by Dietrich Georg Kieser and Karl Ernst von Baer, foreshadow Mathias Jacob Schleiden's and Theodor Schwann's cell theories.

In Oken's time the level of sophistication with respect to scientific evidence was becoming more professionalized in the context of scientific institutions such as the Gesellschaft Deutscher Naturforscher und Ärzte resulting from the criteria that they set for scientists' membership;