75 YEARS

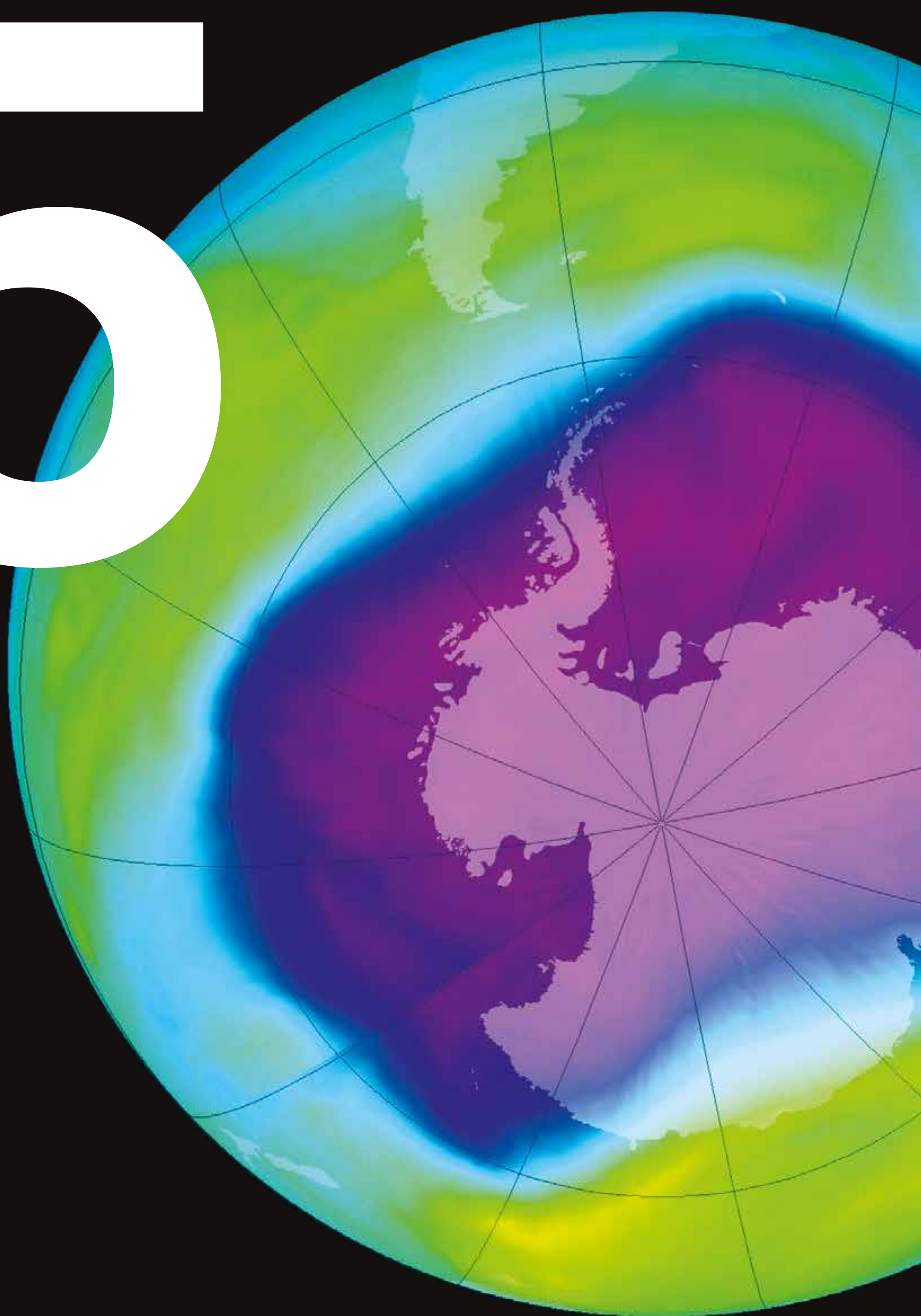
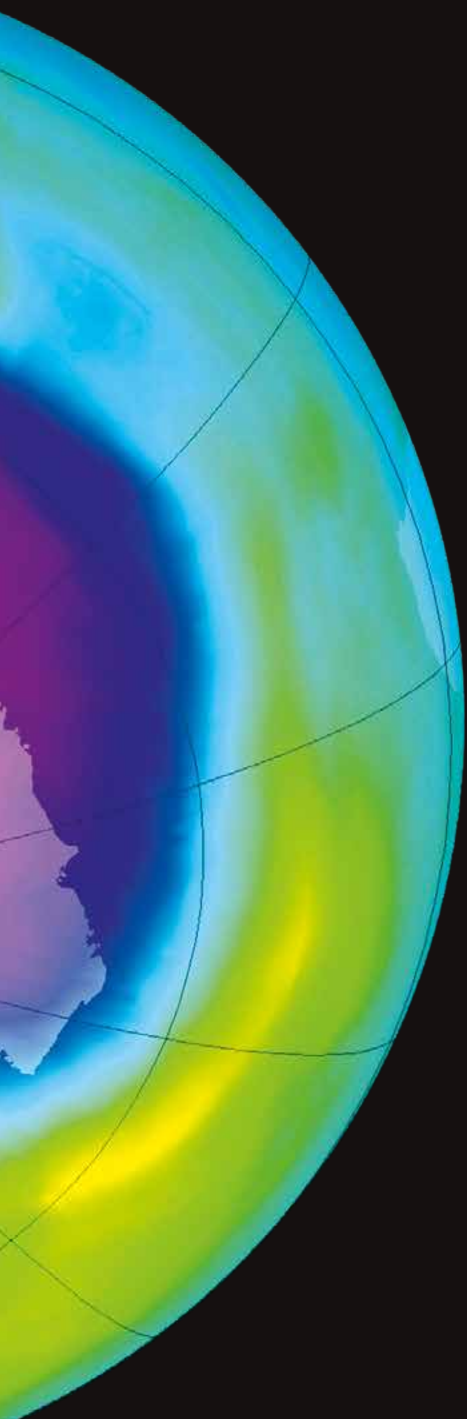


IMAGE: SCIENCE PHOTO LIBRARY / NASA

Delayed recovery: the human-induced ozone hole over Antarctica reached a maximum of 29.5 million square kilometers on September 9, 2000, and on September 24, 2006. Since then, the ozone hole has slowly been shrinking again.



MONITORING THE EARTH'S VITAL SIGNS

TEXT: ROLAND WENGENMAYR

Climate crisis, species extinction, ozone depletion – undesirable ecological trends threaten life on Earth as we know it, and with it the very stability of society. The associated dangers are very well understood. This is the focus of the Earth system cluster at the Max Planck Society. Two later Nobel laureates, Paul J. Crutzen and Klaus Hasselmann, played a major role in its creation.

Looking from outer space, it is immediately clear which species dominates the Earth today. At night a network of lights parallels human activity; during the day, it is made evident by the many human-made structures. Humans have also long left traces in the ground. As early as 1873, this led the Italian geologist Antonio Stoppani to refer to the "Anthropozoic" era in a textbook. However, the fact that this term has arrived in general vocabulary today, slightly altered to "Anthropocene," can be traced back to Paul J. Crutzen. In 2000, at a conference of the International Geosphere Biosphere Programme in the Mexican city of Cuernavaca, during a colleague's lecture, the Max Planck researcher and Nobel laureate in chemistry declared: stop talking about the Holocene – we live in the Anthropocene! The Holocene is the current geological epoch of Earth's history. But this term does not take into account the massive influence of humans on the Earth.

This anecdote is told by Jürgen Renn, Director at the Max Planck Institute for the History of Science in Berlin. He is currently working on setting up the Max Planck Institute of Geoanthropology, which has been in development since 2022, at the site of the former Max Planck Institute for the Science of Human History in Jena. It is the latest within a cluster of Max Planck Institutes researching different facets of the Earth system. The Earth system comprises the totality of all the interacting spheres of the Earth: the atmosphere, that is, the envelope of air; the hydrosphere, the envelope of water, particularly the oceans; the lithosphere, the world under our feet and deeper rock layers; the cryosphere in the icy regions; the biosphere. And that is not all. Renn

⟶

PHOTO: GERMAN AEROSPACE CENTER (DLR)

High-flyers: researchers at the Max Planck Institute for Chemistry are using the Halo research aircraft, which is suitable for extreme altitudes, to analyze trace gases in the atmosphere and the spread of pollutants.

Stop talking about the Holocene – we live in the Anthropocene!

PAUL J. CRUTZEN

also includes the infrastructure created by humans, because this infrastructure is now comparable to the biosphere in terms of weight and energy alone. "The technosphere does indeed stand out from the biosphere," he says, "and when we take the Earth system perspective, it makes sense to treat this sphere in a similar way to the other Earth spheres – not just in isolation, of course, but in their interaction with the other Earth spheres."

As a first research goal, the new Institute in Jena is to investigate "the dynamic development of this coupled human-earth system," says Renn. This is to be achieved in an interdisciplinary collaboration of researchers from the social sciences, the history of science, climate research and archaeology. Linked to this, the institute is also to tackle the issue of the "Great Acceleration." This term is based on the observation that all significant human interventions in the Earth system in the last two centuries have not only taken place very quickly compared to geological processes, for example, but they also seem to experience an exponential acceleration. The researchers in Jena intend to investigate whether this is actually the case and, if so, which influences are significant in the human-Earth system.

The Max Planck Institute of Geoanthropology will therefore deal with issues associated with the climate crisis, which no longer only relate to the various disciplines of the natural sciences, but are now also a research focus of the humanities, social sciences, and human sciences. Geoanthropology, with its new dimension of interdisciplinarity, now complements Earth system research in the Max Planck Society, whose beginnings date back to the 1960s – even if the term "Earth system research" had not yet been coined at that time.

"The term originated in the 1980s, in the run-up to the International Geosphere-Biosphere Programme," explains science historian Gregor Lax, who has researched the formation of the Earth system cluster at the Max Planck Institute for the History of Science. Between 1986 and 2015, the International Geosphere-Biosphere Programme examined various aspects of global change attributable to human activities. When the program was initiated, Earth system research in the Max Planck Society was already advanced enough for the Society to participate.

The Gaia hypothesis, according to which life, together with the inorganic world, forms a complex system that regulates itself, is important to the history of the field. The hypothesis was developed in the early 1970s by the British researcher James Lovelock – together with American evolutionary biologist Lynn Margulis. The two scientists also propagated the Gaia hypothesis through their books. "And in 1983 the term Earth system science was added by a Nasa committee," explains Lax.

One origin of the field of research lies in the early 1960s in the Meteorological Institute of the University of Stockholm, headed by Crutzen's doctoral supervisor Bert Bolin; the other origin is in the USA. Here two marine research institutes led the way: the Scripps Institution of Oceanography in La Jolla, California, and the Woods Hole Oceanographic Institution in Woods Hole, Massachusetts. While Bolin, as a meteorologist, primarily focused on the atmosphere, oceanography dominated in the USA. Klaus Hasselmann conducted research in La Jolla as a young assistant professor in the early 1960s. In 2021, he became the second Max Planck scientist to receive the Nobel Prize in the field of Earth system research.

In the 1960s, however, the Max Planck Society was virtually absent from the newly emerging field of research, reports Lax. This only changed when it proved very difficult to appoint a new head of the Max Planck Institute for Chemistry in Mainz, who could continue the previous →

PHOTO: ARCHIVE OF THE MAX PLANCK SOCIETY

His life's mission was environmental research: Paul J. Crutzen was instrumental in understanding ozone depletion. He promoted Earth system research in the Max Planck Society, as well as the spread of the term Anthropocene. The Nobel Prize winner died in 2021.

PHOTO: PICTURE ALLIANCE/UNITED ARCHIVES/FRANK HEMPEL

Global warming detective: Klaus Hasselmann developed the statistical methods with which his group demonstrated the human fingerprint on the climate for the first time in the 1990s.

field of research at the Institute. This reached the point that the Max Planck Executive Committee even discussed the closure of the Institute; however, the number of employees was too large for this. In addition, the Department of Cosmochemistry had a worldwide reputation. For example, at the end of the 1960s it received moon rocks from the Apollo 11 mission for analysis – one of the largest samples received by an institution outside the United States. After several unsuccessful attempts to fill the role, the Max Planck Society decided to realign the Institute's research and contacted the meteorologist Christian Junge from the University of Mainz, whom it eventually appointed. In the 1950s in the USA, for example, through balloon experiments in the stratosphere, Junge discovered an aerosol layer made up of sulfuric acid particles – the Junge layer named after him.

As Director, Junge radically redirected the Institute's research from 1968 onwards and established a department for atmospheric chemistry. As environmental awareness generally grew in the 1970s, research into chemical trace substances and their cycles on Earth gained increasing attention. And the new Mainz research facility also enhanced its reputation internationally. In 1980, Junge finally succeeded in attracting an emerging talent in atmospheric chemistry to Mainz as his successor: Paul Crutzen, who had previously conducted research at the National Center for Atmospheric Research in Boulder, Colorado.

Crutzen brought computer modeling of chemical processes in the atmosphere to the Max Planck Institute for Chemistry, though this Dutchman was originally a bridge construction engineer. After initially working in that capacity, he applied to the Meteorological Institute in Stockholm, which was looking for a programmer. By his own admission, Crutzen had no idea about programming at the time, but the bright young man got the job, came into contact with atmospheric chemistry, and also went on to study meteorology. As early as the mid-1960s, he researched a phenomenon that was also to become very politically relevant: the catalytic destruction of ozone in the atmosphere by nitrogen oxides, but also by chlorine-containing substances such as chlorofluorocarbons

(CFCs). These studies received special mention in 1995 when Crutzen, as well as Mexican-born Mario Molina and American Sherwood Rowland, two other pioneers of ozone hole research, received the Nobel Prize for Chemistry.

Molina and Rowland showed in 1974 that the halogenated hydrocarbons in spray cans, refrigerators, and many industrial processes can destroy the ozone layer and with it the protection against harmful ultraviolet radiation from space. Around the same time Paul Crutzen, partly together with Frank Arnold from the Max Planck Institute for Nuclear Physics in Heidelberg, researched ozone depletion in the atmosphere. At least in the USA, the environmental movement made the existential danger of an ozone hole widely known and backed up the two US-based chemists Molina and Rowland against the powerful industrial lobby.

In the Federal Republic of Germany, the Federal Government took action in the late 1970s, for example, with the "Blue Angel" eco-label for CFC-free spray cans. In 1985, the ozone hole over Antarctica was discovered, which also accelerated the political agreement on an international ban on hydrogen halides. In September 1987, the international Montreal Protocol was adopted to protect against substances that deplete the ozone layer. The Federal Republic of Germany was one of the first of the 198 signatories, and in October 1987, the Bundestag founded the Enquete Commission on "Preventive measures to protect the Earth's atmosphere" in which delegates and researchers were to submit proposals for the implementation of the Montreal Protocol.

Through a special arrangement, Paul Crutzen, although Dutch, was able to participate, as Hartmut Graßl recounts. At the time the climate researcher was Director of the Institute of Physics at the GKSS Research Center near Hamburg, and moved to the Max Planck Institute for Meteorology in 1988 as Director. Graßl also joined the commission later and learned there how the German industrial lobby fiercely resisted the ban on CFCs. He witnessed how the Chairman of the Enquete Commission, the CDU politician Bernd Schmidbauer, "really snapped at" the industry representative: "When will you finally abandon these delaying tactics? These substances must be stopped!" This made it quite clear, according to Graßl, that even the CDU, the party that formerly supported the industry, now wanted the phase-out. In the end, the Enquete Commission decided on a document that was "translated into English almost word for word and incorporated into the tightening of the Montreal Protocol of 1990," reports Hartmut Graßl.

Klaus Hasselmann's research on human-induced climate change was just as socially relevant as Paul Crutzen's discoveries on ozone depletion in the atmosphere, and continues to be relevant today. And just as Crutzen did not take the direct route into atmo-

⟶

PHOTO: SUSANNE BENNER/MPI FOR CHEMISTRY

The highest research tower in the world: using the 325-meter Amazon Tall Tower Observatory, Atto for short, researchers are investigating, among other things, the CO_2 exchange between the Amazon Rainforest and the atmosphere.

PHOTO: MPI FOR DYNAMICS AND SELF-ORGANIZATION

Max Planck researchers launched CloudKites balloons in the Caribbean in 2020, from the research vessel Maria S. Merian, to study the microprocesses in tropical clouds. The Eurec^{4}a project aims to clarify the influence of global warming on cloud and precipitation formation in the tropics – an important but not yet fully understood feedback effect in climate change.

spheric research, Hasselmann's career also initially took a detour into climate research and then to the Max Planck Institute for Meteorology. As a young scientist, he became known in wave research because he found a way to accurately calculate the spectrum of the different wavelengths in a sea swell – a problem highly relevant to shipping.

Hasselmann's outstanding skills as a theoretical physicist were the reason that the Max Planck Society became aware of him and appointed him the founding Director of an Institute whose research focus was new to him. As the designated Director, he was even involved in the planning of the Institute, whose genesis is extraordinary in two respects. Firstly, it emerged from the Fraunhofer Institute for Radiometeorology and Maritime Meteorology. And secondly, the impetus came from the Federal Ministry of Research, which in 1973 asked the Max Planck Society whether it could take over the Fraunhofer Institute. Although the Institute was highly regarded internationally, it was not well aligned with the Fraunhofer Society, whose focus was on applied research.

Hasselmann recounted the story of when he started working at the Max Planck Institute for Meteorology to his longstanding colleague Hans von Storch, who conducted interviews with Hasselmann over several years and published them in 2021 in a book about the newly awarded Nobel Prize winner: "Everyone expected us to buy a huge computer and start calculating. And it was clear to me that we had not yet understood many of the fundamental questions about climate change and human influence on the climate. My main objective was to clarify the fundamentals of human influence on the climate. How can we distinguish between natural and human-induced climate fluctuations?"

These questions led to a difficult problem: How could long-term climate trends be demonstrated amidst the tremendous background noise of weather fluctuations? And how could we detect the still comparatively tiny, but in the long run important signal that humans leave as a fingerprint in the climate system through the release of greenhouse gases? Hasselmann actually answered these questions with two research papers. On this basis in the mid-1990s, his team in Hamburg demonstrated with a high degree of certainty that humans are changing the climate. The simulation of climate models on supercomputers had long since become indispensable. Under

SUMMARY

The Earth System Cluster at the Max Planck Society conducts basic research related to global change which is attributable to human activities.

The Max Planck Institute for Chemistry in Mainz has been studying atmospheric chemistry since 1968. Paul J. Crutzen, whose findings on the depletion of atmospheric ozone contributed to the ban on halogenated hydrocarbons, has been conducting research there since 1980 and was awarded the Nobel Prize in 1995.

At the Max Planck Institute for Meteorology in Hamburg, Klaus Hasselmann demonstrated the human influence on the climate from 1975 onward, and was awarded the Nobel Prize for Physics in 2021.

The Max Planck Institute for Biogeochemistry in Jena has been researching global material cycles, including carbon and carbon dioxide, since 1997. Since 2022, the Max Planck Institute for Geoanthropology in Jena has been looking into the influence of humans within the Earth system, taking into account aspects of the humanities, social sciences, and human sciences.

Hasselmann's aegis, the German Climate Computing Center was founded in Hamburg and went into operation in 1988.

Shortly before, Paul Crutzen had already established a new field of Earth system research in Mainz: biogeochemistry. It explores the interactions between the atmosphere, the geosphere, and the biosphere. In 1987 he recruited Meinrat O. Andreae, an expert on material cycles in the environment, as Director of the Institute. However, Andreae initially had difficulties in establishing the new term biogeochemistry in the presidium of the Max Planck Society, says Lax. But this would quickly change.

After reunification in 1990, in the course of the reconstruction of East Germany, the Max Planck Society founded new institutes there. In 1994 it organized an International Symposium on Biogeochemical Cycles and Global Change. The Bayreuth biology professor Ernst-Detlef Schulze outlined how he would envisage a future biogeochemical institute. The plant ecologist had met Crutzen and Hasselmann in the 1980s. Crutzen considered the new Institute necessary to investigate the interaction of the soil with its vegetation and atmosphere in more detail. “He said that without robust measurements on the Earth's surface, we are in limbo,” says Schulze.

Beginning in 1997, Schulze was able to realize his ideas for the new Institute, the third major one within the Earth system cluster, as its founding Director in Jena. To this day the scientific objective is the research of global material cycles – carbon, oxygen, hydrogen and nitrogen – and the relevant biological, chemical and physical processes. Jena was chosen partly for political reasons, because Thuringia was also to be considered for a Max Planck Institute. For Schulze, the surroundings of Jena were also scientifically interesting, as the region is geological and has diverse vegetation – ideal for field experiments. At the new Institute, Schulze's team planned tall measurement towers to investigate material transfer between the soil, including vegetation, and the air. The 304-meter Zotto Tower was built in the Siberian Taiga and the 325-meter Atto Tower in the Brazilian Amazon Rainforest. The Max Planck Director also campaigned for the European Union to set up a network of measuring towers in Europe. This Integrated Carbon Observation System today captures the sources and sinks of greenhouse gases across Europe – important data for climate research.

The Earth System Cluster also includes other institutes, currently the Max Planck Institutes for Terrestrial Microbiology in Marburg and for Marine Microbiology in Bremen; the Max Planck Institute for Aeronomy, now Solar System Research, in Lindau, was also temporarily involved. “The Max Planck Society has the ambition to develop new fields of research in Germany,” says historian Gregor Lax. In comparison with other countries, it made quite a late start in terms of Earth system research, but nevertheless became leaders in the field internationally within just a decade. In doing so, its scientists have not simply conducted some outstanding research. With their understanding of ozone depletion and human-induced climate change, among other things, they have laid the foundation for effectively combating these threats to life on Earth as we know it.

THE RESEARCH PROGRAM “HISTORY OF THE MAX PLANCK SOCIETY”

Between 2014 and 2022, independent historians reconstructed the development of the MPG from 1948 to 2002. In doing so, they contextualized the history of the MPG within the contemporary history of the Federal Republic in relation to European and global developments.