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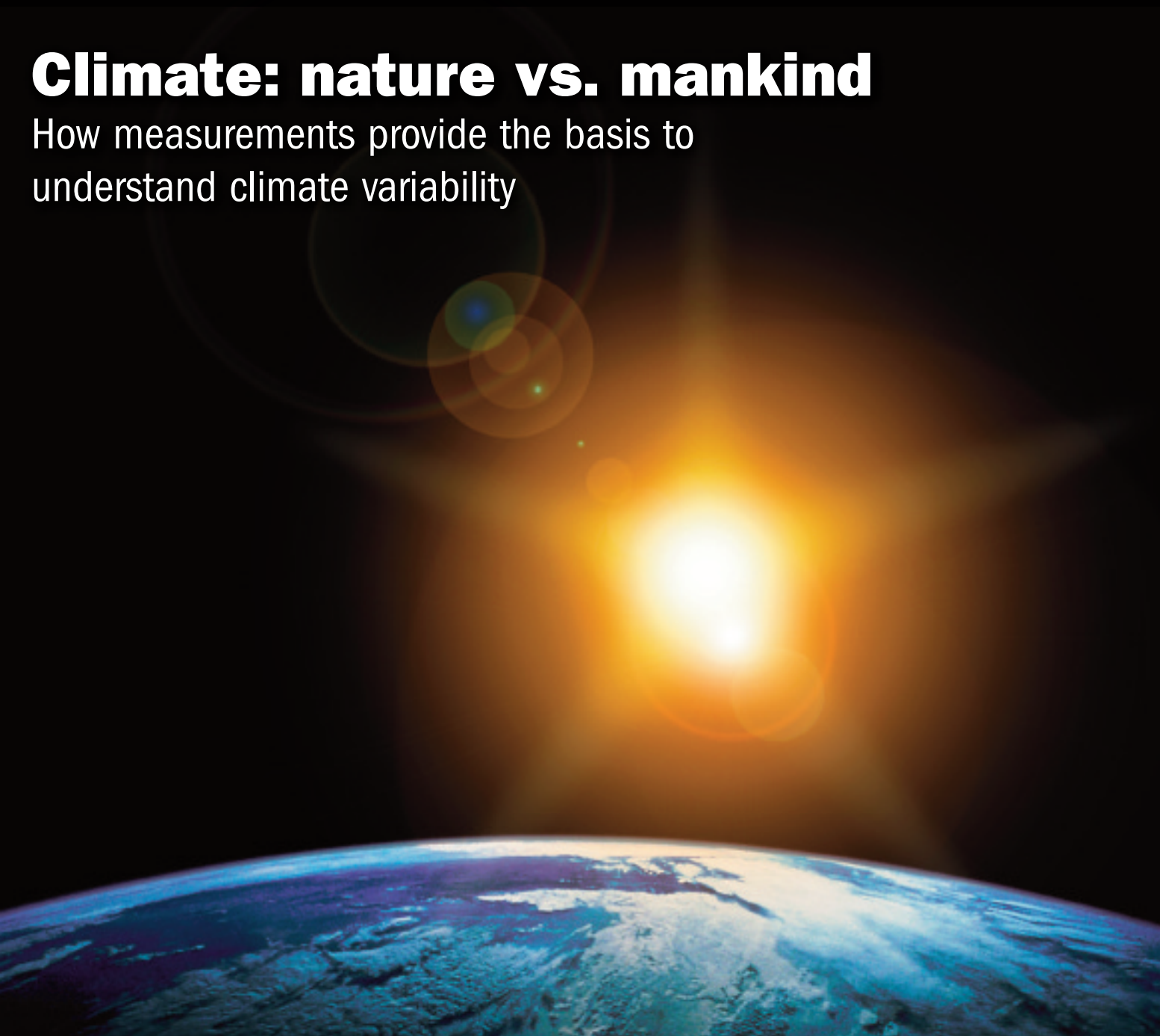

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Essential measurements

Understanding natural and man-made processes in the atmosphere…

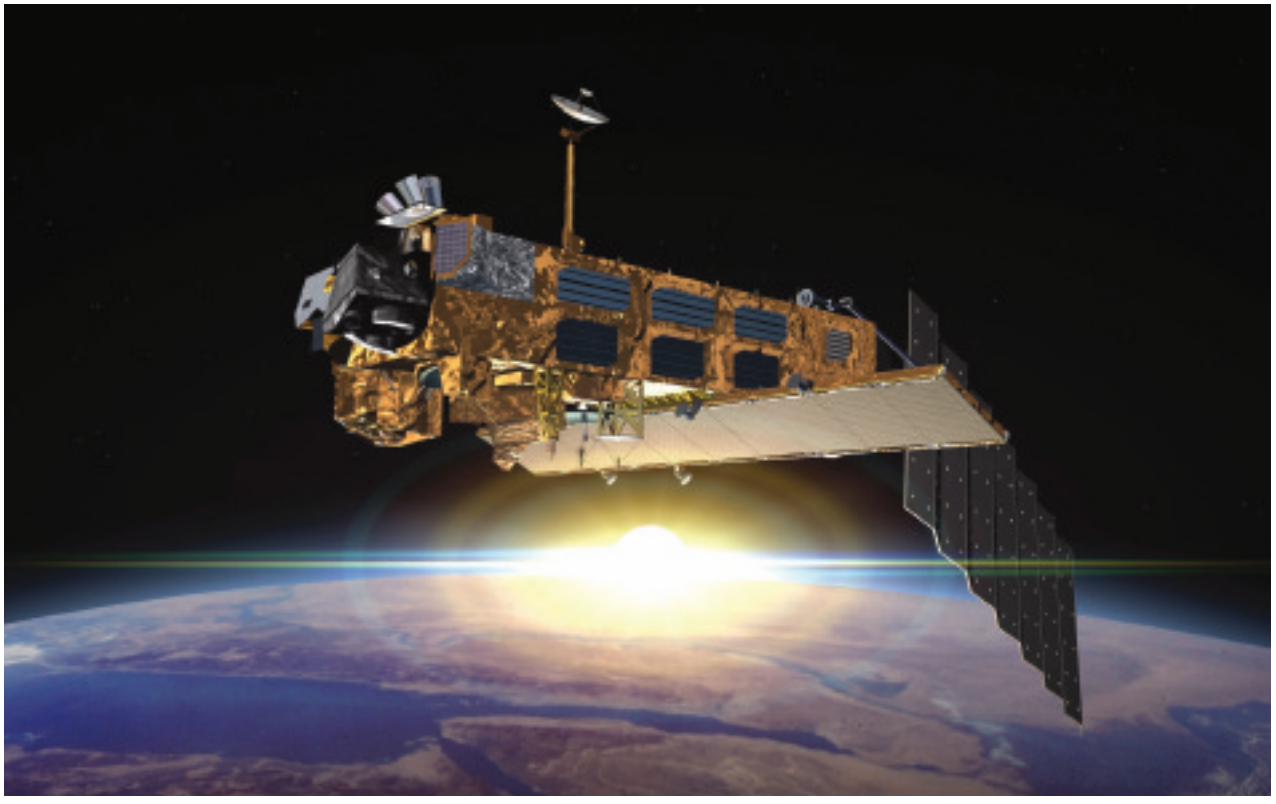
Karlsruhe Institute of Technology (KIT) is one of the leading universities and research institutions in Germany and in Europe. This article will give a brief overview of climate research at KIT, with particular emphasis on the most relevant atmospheric measurements.

The atmosphere is indeed a key component of the Earth's climate. It is also a very complex system that is coupled to the oceans and continental surfaces, to the sun and to astrophysical processes. It is therefore essential to understand and quantify the different natural and man-made processes in the atmosphere and their various contributions to climate changes. In this context, accurate long-term measurements of atmospheric composition are indispensable.

The Institute for Meteorology and Climate Research (IMK) at Karlsruhe Institute of Technology is one of the world's leading research institutes in the observation and modelling of atmospheric composition. Started in Karlsruhe more than 30 years ago when climate research was still an 'exotic' field of science (and even of traditional meteorology), accurate measurements and long-term monitoring of atmospheric composition are today of great interest for policy-makers and the general public.

The Earth's atmosphere is structured in vertical regions that are separated by temperature inversions; the lowest layer (the troposphere) is home of the biosphere and where air pollution occurs. The next highest atmospheric layer (the stratosphere) is where the ozone layer is located, which absorbs most of the solar ultraviolet radiation. Above these lower layers, the Earth's atmosphere becomes thinner and thinner, but even up there, many physical and chemical processes take place that are relevant for climate and meteorology.

Climate change is taking place via changes in atmospheric composition in all these layers. It is also important to understand that climate change is influenced by many feedback mechanisms already in the atmosphere itself. For example, increasing greenhouse gases will lead to warming of the troposphere but to an overall cooling of the stratosphere, so that stratospheric ozone depletion may increase (with enhanced UV radiation leading to increasing ozone formation



The European ENVISAT satellite (in orbit since 2002) carries three instruments for atmospheric research: MIPAS, GOMOS and SCIAMACHY

Launch of a stratospheric research balloon at the ESRANGE facility in Kiruna, Sweden

in the troposphere); furthermore, some greenhouse gases are also harmful to stratospheric ozone. In addition, global warming will lead to an increase in the trace-gas exchange between the troposphere and the stratosphere, with the effect of more ozone depletion in the stratosphere and increasing ozone in the troposphere – which itself is a powerful greenhouse gas.

Unfortunately, it is very difficult to measure atmospheric composition in all vertical layers with high spatial resolution and global coverage. However, such measurements are required to initialise and validate atmospheric models, and to identify the most relevant processes in atmospheric change. A large variety of instruments and platforms are used for atmospheric measurements, which are constantly being improved.

The most powerful instruments are operated on board satellite platforms, such as the European ENVISAT satellite, launched into orbit in March 2002. ENVISAT carries three instruments for the observation of the Earth's atmosphere: GOMOS, MIPAS and SCIAMACHY. The Mid-Infrared Passive Atmospheric Sounder (MIPAS) instrument was proposed by the Institute for Meteorology and Climate Research in Karlsruhe, which played a major role in the development of MIPAS. Karlsruhe is today the leading centre for MIPAS data users.

To date, MIPAS has provided over eight years of unique atmospheric data. MIPAS data will be used for the Essential Climate Variables initiative of the GCOS (Global Climate Observing System). This data has already provided a wealth of new information about the chemical and physical processes in the middle and upper atmosphere. Data from ENVISAT is today complemented and extended by new instruments aboard EUMETSAT's latest generation of meteorological satellites (MetOp) such as IASI and GOME-2. For the future, PREMIER, an advanced sounder focusing on the chemical and dynamic processes in the region between the two lowest atmospheric layers, is currently prepared by ESA as Earth Explorer 7 candidate. Again,

Balloon launch during polar night

the scientists at KIT play a leading role in the scientific and technical development of this new satellite mission, for example with the development of state-of-the-art two-dimensional infrared atmospheric sounders. PREMIER will also be able to provide maps of volcanic ash clouds with very high vertical resolution (500m).

A second important activity in the field of climate research at KIT is the measurement of atmospheric trace substances from air-borne platforms, such as stratospheric balloons and high-altitude aircraft. The scientific balloons can reach ceiling altitudes of up to 40km with payloads of up to one ton of instruments, and operate usually for one or two days. For the future, long-duration balloons are prepared that may stay up to one week at ceiling altitude, thus completing an entire round trip of the polar stratosphere, along the polar circle. These balloon launches are often carried out in polar winter under very difficult conditions, especially those from the ESRANGE base in Kiruna (Northern Sweden) where the ground temperatures can be as low as -40°C.

Parallel to the balloon activities, the climate scientists at KIT have developed scientific instruments operated from high-altitude aircraft such as the Geophysica (M-55), a former Russian Mystic reconnaissance airplane (similar to Lockheed's U-2) that can

The Geophysica M-55 high-altitude aircraft, a former Russian 'Mystic' reconnaissance aircraft, is used today for climate research

The German HALO 'High-Altitude and Long-Range' research aircraft

Gas inlet for the CARIBIC project installed on a commercial Airbus A340-600

reach a ceiling altitude of nearly 21km. The Geophysica was extensively used during the winter of 2009-2010 in the RECONCILE campaign (an EU FP-7 project) to investigate polar stratospheric chemistry, in order to resolve existing discrepancies in our current understanding of ozone depletion.

The newest development in this field is HALO, the German 'High Altitude and Long-Range' Aircraft, a modified business jet from Gulfstream Aerospace. HALO is funded by the German Federal Ministry of Education and Research, the Helmholtz-Gemeinschaft (HGF), and the Max-Planck-Gesellschaft (MPG). HALO will be operated in collaboration with the DLR from Oberpfaffenhofen near Munich.

Commercial in-service aircraft (an Airbus A340-600) is used in the CARIBIC (Civil Aircraft for the Regular Investigation of the Atmosphere Based on an Instrument Container) project where scientists from KIT collaborate with partners in Germany and Europe-wide. CARIBIC has been operating since 2004 and will be part of the IAGOS-ERI (In-service Aircraft for a Global Observing System), one of the new European research infrastructures on the ESFRI Roadmap 2006. IAGOS-ERI will establish and operate a distributed infrastructure for long-term observations of atmospheric composition, aerosol and cloud particles on a global scale from a fleet of 10-20 long-range in-service aircraft of internationally operating airlines. In April 2010, the CARIBIC Airbus A340 was also used by Lufthansa for a flight over Germany and Europe to investigate the volcanic ash cloud that blocked air traffic over Europe for several days.

Last but not least, ground-based measurements of the atmosphere are performed routinely from various observation sites (such as Kiruna in Sweden, Karlsruhe, Izana on Tenerife Island, or Addis Ababa in Ethiopia) as part of the NDACC (Network for the Detection of Atmospheric

The NDACC climate research station in Izana, Tenerife Island, above the clouds

Professor Dr Johannes Orphal, Director of the Institute for Meteorology and Climate Research (IMK) at the Karlsruhe Institute of Technology (KIT)

Composition Change). These observations, started several decades ago, provide the long-term data that is needed to monitor trends and the variability of atmospheric trace substances over timespans of already several decades. Again, the scientists from Karlsruhe play a leading role in the NDACC and other international networks.

"In the future, more atmospheric measurements are needed," says Professor Dr Johannes Orphal, "since our understanding of climate change and its underlying processes is still mainly limited by the available data from atmospheric measurements. This is clearly recognised by the latest assessment report from the IPCC and many other studies." Thus, climate research will remain a priority at KIT in the future, with four large climate research institutes, a dedicated topical centre, and a new graduate school Climate and Environment (GRACE).

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About KIT (www.kit.edu)
Karlsruhe Institute of Technology (KIT), located in Baden-Württemberg in the southwest of Germany, is the largest university and public research centre in Germany, with over 18,000 students, 300 faculty members, 8,000 employees, and with an annual budget of more than €700m. KIT was established in 2009 as the merger of the former University of Karlsruhe (founded in 1825 as the first polytechnical university in Germany) and the former Research Centre Karlsruhe (part of the Helmholtz association). KIT is one of the leading universities in Germany, ranked by the EU as the second university in Germany and sixth in Europe in terms of scholarly impact. In Karlsruhe, Heinrich Hertz demonstrated the existence of electromagnetic waves back in 1887. Amongst other famous scientists who worked or studied in Karlsruhe, one finds Carl-Friedrich Benz (the inventor of the automobile), Karl-Friedrich Braun (who constructed the first cathode-ray tube and won the Nobel Prize for Physics in 1909), the chemist Fritz Haber (who received the Nobel Prize in 1918 for the synthesis of ammonia), and Edward Teller, one of the pioneers of molecular quantum mechanics and the Manhattan project.

KIT Centre Climate & Environment (www.research.kit.edu/749.php)
The centre comprises 30 institutes and about 500 employees of KIT. Activities are based on well-established KIT facilities, such as the Institute of Meteorology and Climate Research (IMK), the Excellence Centre CEDIM (Centre for Disaster Management and Risk Reduction Technology, in cooperation with GeoForschungs-Zentrum Potsdam) and with the cedim AG, several large-scale projects on integrated water resources management (IWRM), the Competence Centre for Material Moisture (CMM), and many research projects.

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