MEASURING, PROJECTING, TAKING ACTION

The 23 UN Climate Change Conference has just taken place in Bonn – another important step for the international community in facing the challenges of global climate change. We need to reduce the anthropogenic impact on the climate system – the disruption caused by humans. Current climate and Earth system research provides unprecedented volumes of data of exceptional quality. Veronika Eyring is Chair of the Coupled Model Intercomparison Project (CMIP) Panel that coordinates global climate model simulations worldwide within the framework of the World Climate Research Programme (WCRP). Bernadette Jung from the DLR Communications Department in Oberpfaffenhofen spoke with her.

Three decades of atmospheric research at DLR

New Earth observation and climate modelling data help to expand our scientific foundation of climate change and to answer questions that are relevant to the action required: How exactly does the climate system work? What are the causes of climate change? What are the implications? At the DLR Institute of Atmospheric Physics in Oberpfaffenhofen, researchers investigate these issues.

Climate data unprecedented in scope and improved models for one of humankind's greatest challenges

Interview with DLR climate researcher Veronika Eyring

There is a growing need for scientific information and knowledge about climate change. What role does climate modelling play here?

: Numerous influencing factors and interdependencies make the climate a highly complex system. Climate models are numerical tools that simulate these interactions and feedbacks. They are used to understand the past and present-day climate, and for providing projections on future climate. The modelling requirements have increased in line with the need for information. Modern Earth system models are already able to take into account a wide range of factors – from the complete atmospheric chemistry and dynamic land surface processes, including vegetation, through to land and ocean carbon cycles. The horizontal and vertical resolution of the models is also increasing. In my group on Earth System Model Evaluation, we investigate the quality of various models in comparison to observational data. This gives us a better understanding of the processes of the climate system and can guide future development of the models. It is also a vital prerequisite for trustworthy climate projections of the 21st century that are urgently needed by society, government and industry.

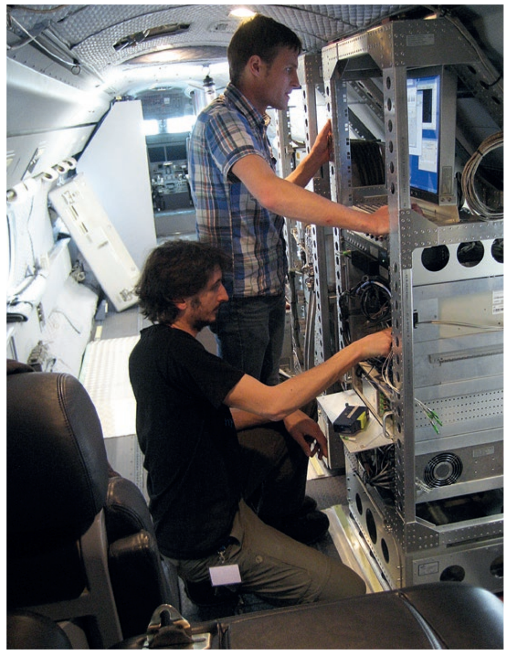
The research aircraft HALO (High Altitude and Long Range Research Aircraft) investigates how clouds in clean air above the rainforest differ from those in deforested polluted regions. This image was acquired from the flight deck over the nose boom in front of a thunderstorm over the Amazon.

How are these research results used?

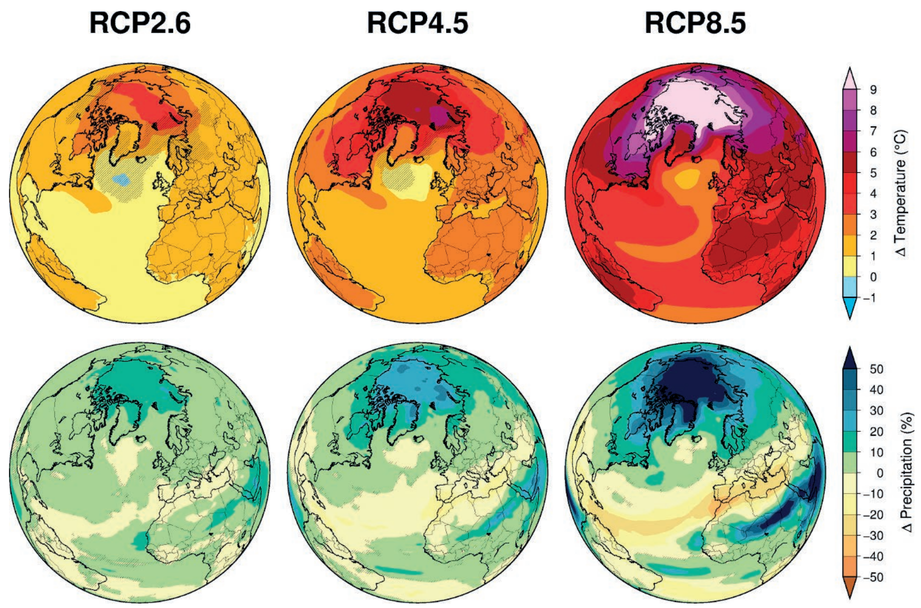
: Under the auspices of the World Climate Research Programme (WCRP), hundreds of climate researchers are working in modelling centres around the world, sharing, comparing and analysing the latest results from global climate models. As part of the Coupled Model Intercomparison Project (CMIP), simulations provide important data to the research community for the next five to 10 years. The Intergovernmental Panel on Climate Change (IPCC) uses the CMIP simulations as an important source – for example for its last full 2013 Assessment Report, which provided the scientific basis for the Paris Agreement and led to the adoption of the two-degree climate target. This encourages us in the Earth System Modelling department to make a significant contribution to the Sixth Assessment Report. On the one hand, our climate simulations with the EMAC model (ECHAM/MESSy Atmospheric Chemistry) are contributing to CMIP6 and, on the other, we are further developing the Earth System Model Evaluation Tool (ESMValTool) and applying it to CMIP6 simulations. This enables us to routinely check the models against observational data.

More complex climate models, more accurate projections– where are the next challenges?

: One of the main challenges involves the area of Big Data. Thanks to rapid scientific and technological progress, our data stores are reaching entirely new dimensions. This is good news, but it challenges the capacity and creativity of the largest data centres as well as the fastest data networks. For the current CMIP project phase alone, we are expecting a data volume of 20 to 40 petabytes – an increase by a factor of 10 to 20 compared with the CMIP5 model archive from 2013. In the coming years, more than 30 international climate modelling groups will be delivering CMIP6 model data. This data must be archived, documented, distributed and analysed. In addition, Earth observation data from the EU Copernicus satellite programme and other satellite missions, from aircraft measurement campaigns and ground stations have to be processed and provided. In Oberpfaffenhofen, we have been active in this area for a long time and have developed the ESMValTool – a tool for efficiently evaluating the models with observational data. This tool is also routinely applied to CMIP6 simulations at the German Climate Computing Center (Deutsches Klimarechenzentrum; DKRZ).



Preparation for a test flight with the Franco-German climate mission MERLIN (Methane Remote Sensing Lidar Mission) on board HALO. CHARM-F will be tested on the flight. CHARM-F (CH4 Airborne Remote Monitoring) is an aircraft-borne integrated path differential absorption (IPDA) lidar. It can be used to quantify gradients of concentration as well as carbon dioxide and methane land-atmosphere fluxes, both from anthropogenic point sources and from broader natural sources



Climate model projections based on three different scenarios, where carbon dioxide concentrations increase from RCP2.6 (Representative Concentration Pathways) to RCP8.5.

The upper row shows changes to the two-metre temperature, as calculated towards the end of the 21st century (averaged for the years 2090 to 2099) compared with the period 1986 to 2005. The associated relative changes in precipitation are shown in the bottom row. All these results are the averages of a total of 26 different CMIP5-generation climate models, so-called 'multi-model means'.

(Illustration generated with ESMValTool www.esmvaltool.org).

You are also involved in the establishment of the new DLR Institute of Data Science in Jena.

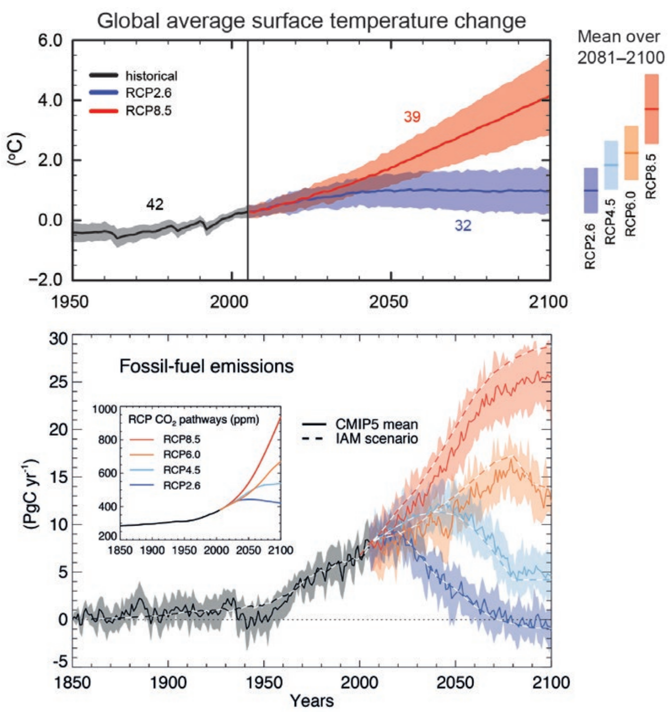
: Yes, I am supporting the set-up of a climate informatics group that will work in collaboration with our institute, the Friedrich Schiller University in Jena and the Max Planck Institute for Biogeochemistry. Our goal is to develop innovative, efficient methods for data management and data analysis. Climate informatics is an exciting new research area that takes Earth system data from models and satellites to a new level. If we enhance the ESMValTool with suitable data science methods, we can find new ways of detecting changes in the climate system early on. In addition, by making use of IT methods and the research at our Institute we want to further reduce existing uncertainties in climate model projections.

In the climate debate, there are also people who deny anthropogenic climate change. What does climate modelling have to say about that?

: 'Sensitivity simulations' are used to distinguish the effect of humans on the climate from other, naturally occurring factors. By doing this, model simulations that only take into consideration natural forcings are compared with those that consider both natural and anthropogenic forcings. The above-mentioned fifth IPCC Assessment Report came to the conclusion that human influence on the climate system is clear. This is evident from the increasing greenhouse gas concentrations in the atmosphere and in positive radiative forcing. Furthermore, there are observations of global warming and other climate indicators, as well as our own improved understanding of the climate system.

Determining the greenhouse effect is critical for climate projections. Where do you get the necessary data?

: To evaluate the model, we primarily need long-term measurements, such as those supplied by the DLR Earth Observation Center (EOC) and the ESA Climate Change Initiative (CCI) programme. The emission of the two most significant greenhouse gases – carbon dioxide and methane – can be measured in situ, meaning directly in the atmosphere using research aircraft or satellites. We expect a breakthrough in our understanding and the analysis of regional methane emissions in the coming years, when the German-French MERLIN satellite mission is launched in 2020. To prepare for this mission, the MERLIN aircraft demonstrator CHARM-F is currently being used in measurement campaigns by our Institute on board the High Altitude and Long Range Research Aircraft (HALO). We specifically target and measure both anthropogenic and natural sources of methane and carbon dioxide. With MERLIN, we will be able to collect a global data set from an altitude of 500 kilometres and monitor methane emissions released by permafrost soils or ocean sediments as a result of global warming.



At the UN Climate Change Conference in Paris (COP21) in December 2015, a total of 195 countries reached a general, global climate protection agreement that is binding under international law – a first. The agreement comprises a global action plan aimed at limiting global warming to significantly less than two degrees Celsius, in order to counteract dangerous climate change. To do so, greenhouse gas emissions, in particular, must be significantly reduced as quickly as possible and, in the coming decades, be cut to zero.

Top diagram:
Current results of the IPCC on the future changes to the global surface temperature, depending on different emission scenarios (Representative Concentration Pathways, RCPs). The blue curve here corresponds to the two-degree target, while the red curve is a 'business as usual' scenario.

Bottom diagram:
RCPs and associated atmospheric carbon dioxide concentrations (inset). It should be noted that the RCP2.6 scenario, which represents the two-degree target, requires negative emissions in the second half of the 21st century, meaning that the net amount of carbon dioxide must be removed from the atmosphere.

Source: IPCC 2013, AR5, Fig. SPM 7 and Fig. TS19

The two-degree target of the UN Climate Change Conference in Paris is a major challenge. Can DLR climate research support the implementation of this goal in Germany?

: For Germany, as an industrial location, the challenge lies in maximising effective climate protection measures while minimising the impact on the competitiveness of the economy. DLR has been making significant contributions to key research areas for many years. Technological solutions for preventing greenhouse gas emissions entail a transformation of the energy sector, industry and the aviation and transport sectors. Since the necessary measures will have far-reaching economic consequences, they must first be evaluated according to the best of our scientific and technical knowledge. This requires an in-depth understanding of the Earth system, particularly with regard to its carbon and energy processes. The scientific foundations and analytical processes are constantly being expanded by our Institute and the international research community. With satellite missions such as MERLIN or Tandem-L, DLR is capable of developing the global climate and environmental observation systems of tomorrow. Such observation systems are essential if we are to verify the effectiveness and compliance of climate protection measures. Furthermore, the other economic and social consequences of the planned measures must also be taken into account. In addition, our Institute is investigating the climate impact of transport and aviation emissions, including those that are not caused by carbon dioxide emissions (for example, contrails, cirrus clouds and ozone). We are also working on optimising flight paths. The resulting cost-benefit analysis is compared with alternative concepts for design and flight guidance in order to find ways to reduce the impact of aviation on climate.

Veronika Eyring
is Head of the Earth System Model Evaluation Group at the DLR Institute of Atmospheric Physics in Oberpfaffenhofen and is Professor of climate modelling at the Institute of Environmental Physics at the University of Bremen. Since 2014, she is Chair of the CMIP Panel, which coordinates climate modelling simulations worldwide. Professor Eyring is currently supporting the establishment of a working group in the area of climate informatics at the new Institute of Data Science in Jena.

CMIP – Coupled Model Intercomparison Project

CMIP was launched 20 years ago as a research initiative to compare the first global climate models. Today, several hundred scientists pool their expertise here. The aim of CMIP is to gain a better understanding of past, present and future climate change. To be able to compare modelling results, CMIP develops – among other things – standards for simulations, data formats and evaluation algorithms. This gives climate researchers the possibility of sharing, comparing and assessing their findings. CMIP model output therefore represent one of the most important sources of robust and reliable climate information.