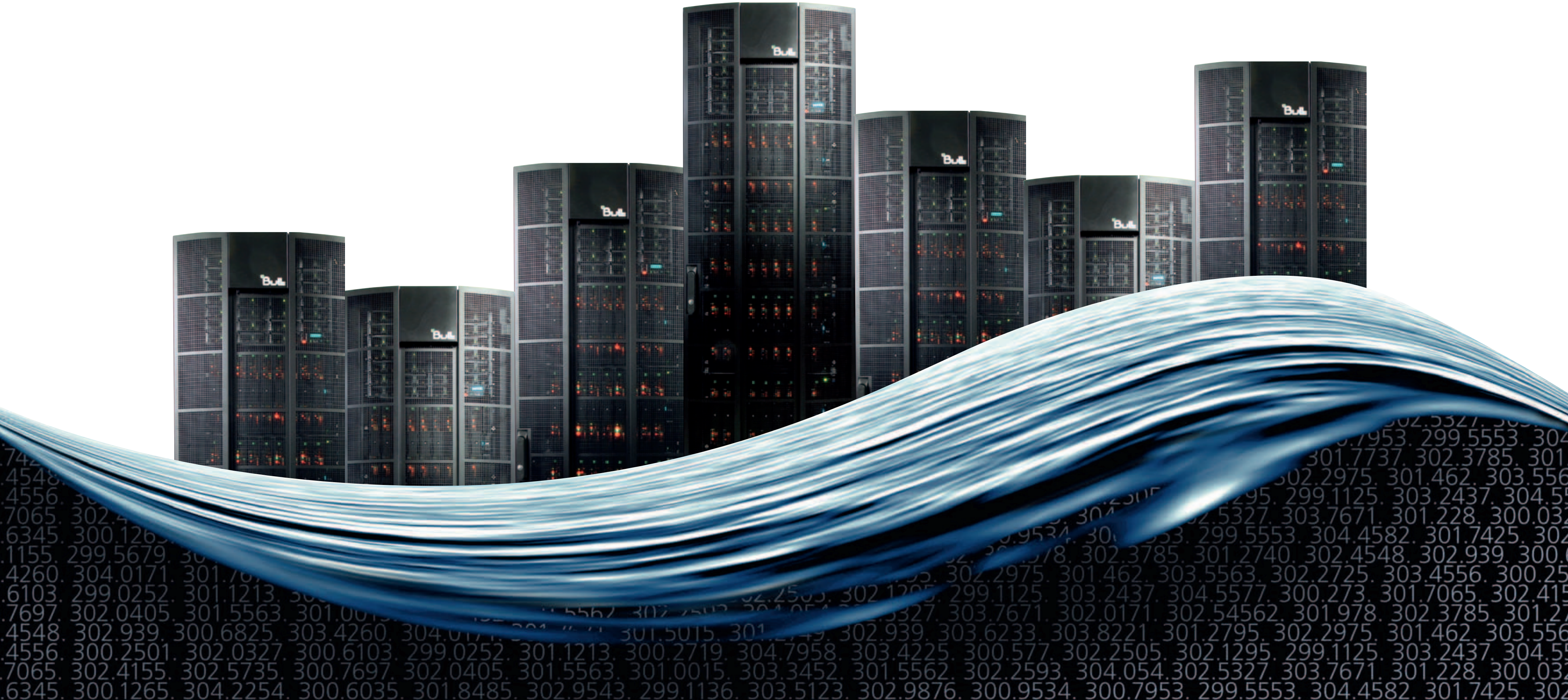
DKRZ
DEUTSCHES KLIMARECHENZENTRUM

Computers, Data, and Knowledge

The German Climate Computing Center: Partner for Climate Research



Contents

Top facility for climate and climate impact researchers

What influences our climate? Will it continue getting warmer on Earth? How quickly will sea level rise? And what will the climate be like in the world 50 years from now? These kinds of questions can only be answered using a supercomputer – and with knowledge of its efficient use. The German Climate Computing Centre (DKRZ) offers both, specially tailored to climate research. High-performance computers and enormous data storage facilitate the simulation and study our complex climate system. Continuous expansion of its computing capacity provides a state-of-the-art environment for first-class climate simulations, keeping DKRZ globally competitive. Add to this the 25 years of experience DKRZ provides its users: the highly qualified scientific and technical personnel at DKRZ support the Center's users in optimizing their climate models, displaying their simulation results, and managing their data.

With its hardware, software, and brainware, DKRZ offers a unique research infrastructure for model-based simulations of global climate change and its effects on various regions of the planet. If it involves climate simulations or climate data, DKRZ is key facility for scientists in Germany.

The team

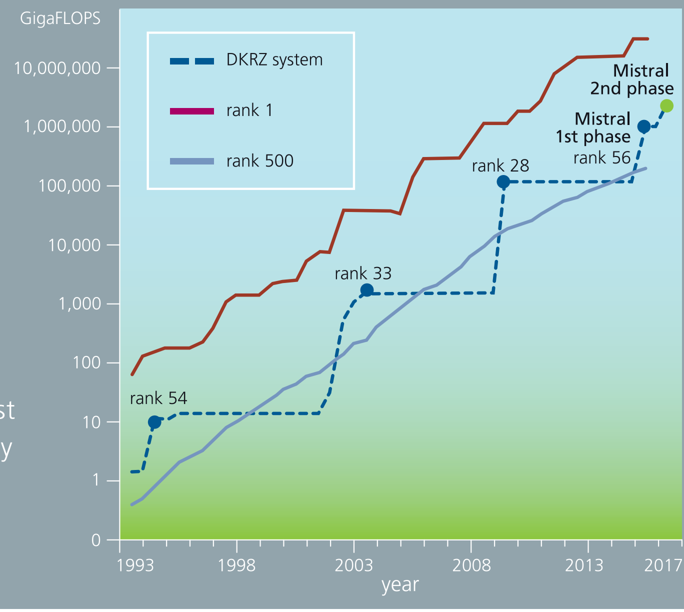
- Knowledgeable in Earth system research
- Specialized in high-performance computing
- Experienced with data management
- Leaders in climate data visualization techniques

Climate and climate impact researchers can be sure: the scientists, technicians, and administrative personnel are committed to providing the best possible research environment.

The technology

- Massively parallel supercomputer: more processing speed and data processing capacity than individual research institutes and universities can provide
- Europe's largest hard-drive system
- One of the largest data archiving systems worldwide

DKRZ is often in the lead: among the 500 fastest computers in the world, DKRZ computers usually occupy top positions shortly after installation (TOP500 List: www.top500.org).

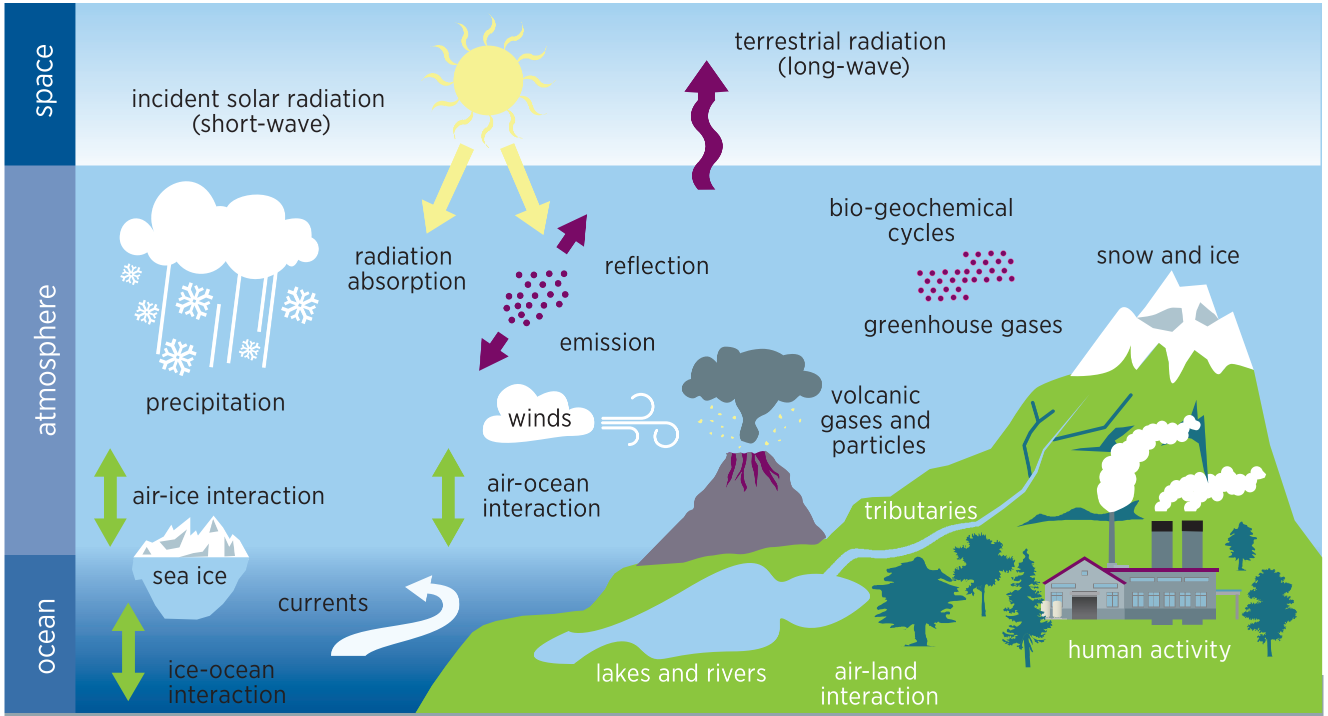


Climate and Models

What is going on with our climate?

The climate of our planet Earth has always undergone natural fluctuations. Earth was at times warming, and then cooled down again. With the help of ice cores, tree rings, fossilized pollen, and sedimentary deposits in the ocean, scientists are reconstructing the climate of the past millions of years. This information is entered into climate models that will provide us with a better idea about the climate system of the past, present, and future.

Today, the Earth is warming at an unprecedented rate. The natural equilibrium that previously provided climate stability over the past millennia has changed since the beginning of the industrialization about 150 years ago. Humans have influenced global climate through their activities. Although this has been proven, there are still many unanswered questions. What changes are human activities responsible for? Which ones arise from natural fluctuations? How accurately can climate change be predicted? What physical, chemical, and biological mechanisms influence climate variability? Many details of the complex processes and interactions of the Earth's systems are still not sufficiently understood.



Interaction of ocean, atmosphere, and outer space

The climate system is an enormous heat engine driven by the radiation from the sun. The differences in the incident solar radiation between the equator and the polar regions, between day and night, as well as between summer and winter create temperature and density fluctuations. This results in winds that drive the ocean currents. The momentum and mass flows and energy flux between the oceans, the atmosphere, snow and ice as well as the surface vegetation determine the internal dynamics of the climatic system on times scales of hours to millennia. In addition, humanity is burning coal and oil, cutting down and burning forests, engaging in industrialized agriculture and animal feedlot operations, building cities – and thus producing greenhouse gas emissions and aerosols. Greenhouse gases impede the radiation of heat back through the atmosphere into space, increasing the natural greenhouse effect, while aerosols primarily act to reduce incident radiation, and therefore exert more of a cooling effect. Over the long term, climate is also influenced by continental drift, the formation of mountains, erosion, as well as changes to the Earth's orbit.

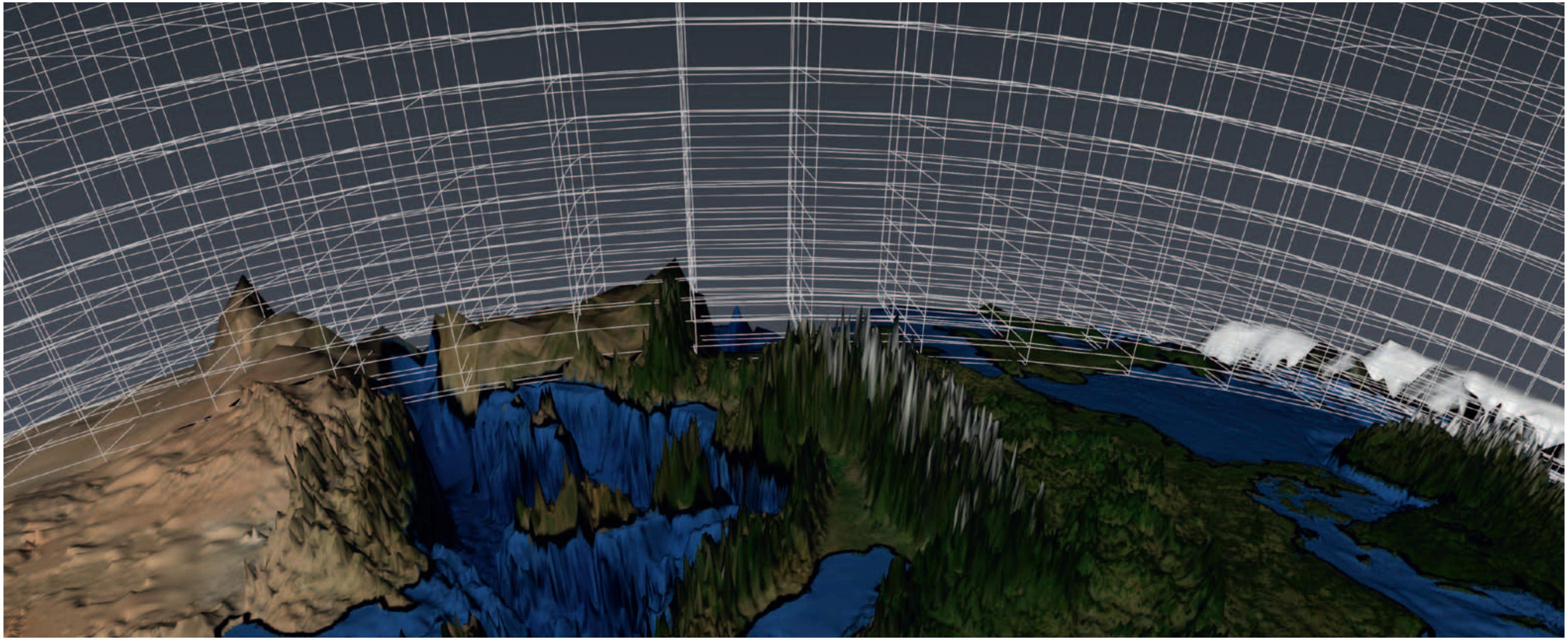
How does a climate model work?

Climatology and conducting climate change research without models would be unthinkable today. The Earth's climate system is too complex and dynamic for that. The models help us understand specific processes, interactions, and regularities of the climate system, and assist in simulating the climate of the past as well as projecting it into the future.

Researchers want to use climate models to emulate the entire climate system. However, the various components such as the oceans, the atmosphere, the land, and sea ice respond at different rates to changes – each of these components has its own characteristic response time. So it is actually counterproductive to place all of the important components of the climate system into a single model. Instead, a coordinated hierarchical system of multiple sub-models has been developed in order to efficiently take into account the various time scales and combinations of subsystems.

It's all in the math

Many processes in the Earth's system are governed by known physical laws. Mathematical equations describe the evolution of climate properties such as temperature and the amount of water vapor as well as the transport of these quantities over a given period of



The atmosphere and oceans are divided into grid cells within the model. The grid system spans the Earth.

time. Unfortunately though, there is no exact solution to these equations. Climate researchers have therefore developed numerical models with which approximate solutions to these equations can be derived by computers.

First, the atmosphere, oceans, and the land are all divided into millions of grid cells. Starting from initial values, approximate solutions to the physical equations that describe motion and fluxes of heat, momentum and mass are computed for each of the individual cells, yielding a prediction for the next incremental point in time. For atmospheric models, a time step in the range of a few minutes is used.

Once all of the values have been calculated, the process is repeated again from the beginning using the new values – and you work your way into the future this way, one step at a time. Only high-performance computers can handle this many simultaneous calculations.

The smaller the grid cells are and the more processes are taken into account, the better the representation of the real-world climate.

Climate modeling is highly complex. For that reason, it requires not only an exact understanding of the physical, chemical, and biological processes in the Earth's systems, but also specialized technical knowledge and experience in programming massively parallel supercomputers.

Climate simulations require the best possible technology

Resolution, reliability, and data analysis – climate modeling requires enormous computing and storage capacity. For this reason, the quality of climate models is strongly dependent on the performance of the computer itself. By contrast, the diverse ways and length of time the resultant mountain of data can be efficiently used is a question of the storage space on the hard drives and the capacity of the magnetic tape archive.

A complex climate system

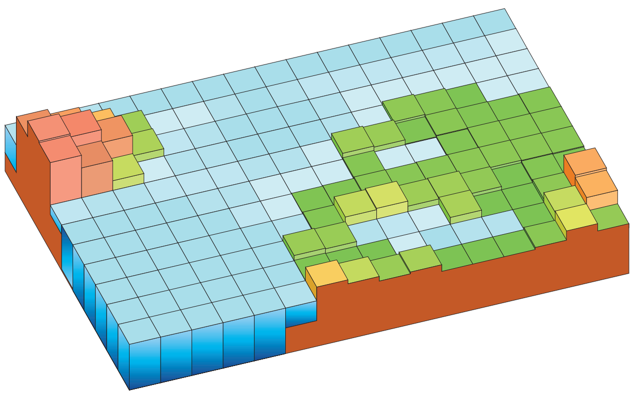
When climate modeling began, researchers concentrated on simulating the physical processes and the coupling between the atmosphere and the oceans, for example. Today, they can also incorporate chemical and biological processes using the high-performance computer at DKRZ. The interaction of climate, society, and the economy can be studied. The primary objective is the development of a complex model of Earth that includes all physical, chemical, and biological interactions between the components of the climate system as well as societal aspects.

Resolution is the key

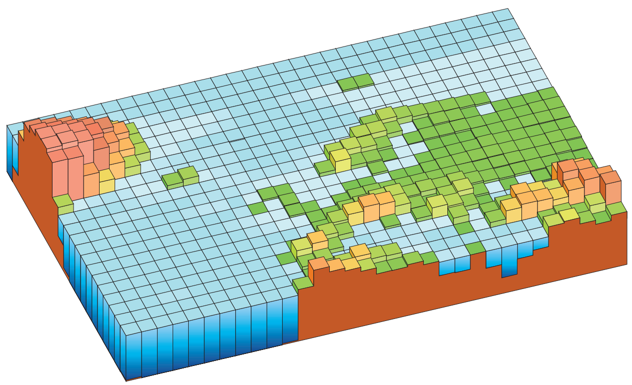
The smaller the grid cells of a climate model are, the higher the spatial resolution of the model is and the more accurate the computational results are. However, if you want to double the resolution, the computing time for studying the same time span goes up a factor of ten. Even the newest supercomputers are still not capable today of calculating complex climate models at resolutions high enough to sufficiently simulate all the important processes occurring at small spatial scales.

Reliable results

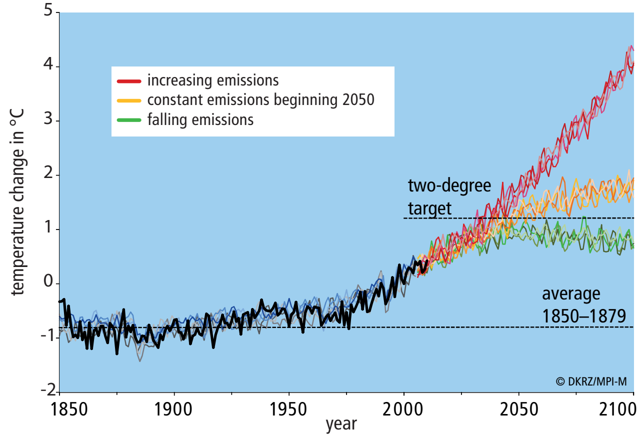
Just how reliable are the results of a climate simulation? A fair question, because numerical methods of calculation are often sensitive to small changes in the initial values. Scientists therefore carry out what are called ensemble calculations. They repeat the calculations with the same model but using slightly different initial values each time. Statistical analyses of the resulting data provide information about how predictive the results ultimately are. This enables statistically significant trends to be differentiated from random fluctuations. The high-performance computer at DKRZ can calculate large ensembles.



Spatial resolution: sample of the computational grid for Europe.
Grid spacing approximately 500 km



Grid spacing approximately 250 km



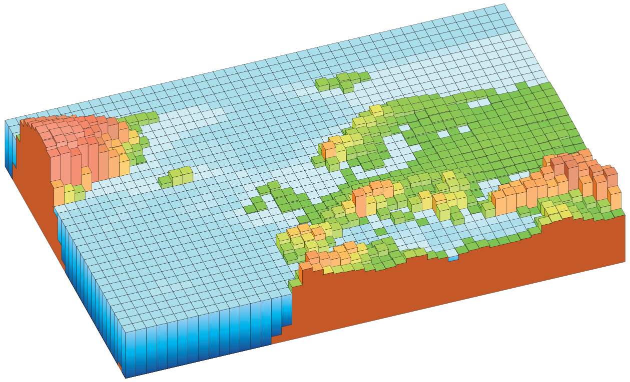
Ensembles: several calculations of changes in global mean temperatures relative to the reference period of 1986 to 2005 using a model from the Max Planck Institute for Meteorology in Hamburg, Germany

Simulating centuries

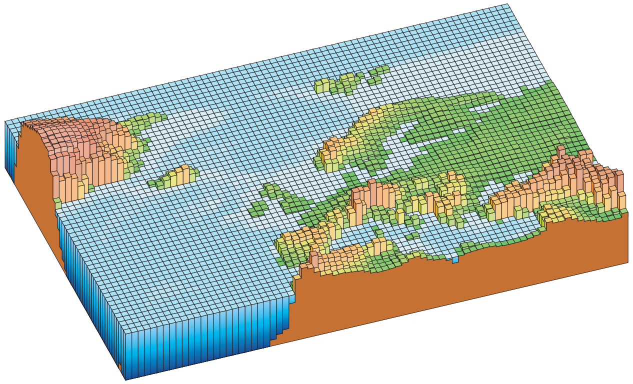
Many studies require simulating climate conditions over several centuries. In order for studies not to take years to complete, long intervals of the extensive periods being studied must be calculated in a few days. Yet even the most powerful supercomputers still need months today to calculate an ice age, for example.

Data, data, and more data

Fast computers are not enough, though. Climate simulations produce enormous quantities of valuable data. The evaluation and analysis of these data can sometimes go on for years. In addition, the data need to be well managed so they can be used for long-term national and international collaborative research. DKRZ possesses one of the largest hard-drive systems on the planet as well as one of the most capable magnetic tape archives. Scientists world wide work with the data stored here.



Grid spacing approximately 180 km



Grid spacing approximately 110 km

Slipping through the sieve

Small-scale spatial processes such as cloud formation are too small to be caught by the sieve of grid cells in global models. However, clouds play an important role in the radiation budget of the Earth. On the one hand, they reflect short wavelengths of incident solar radiation and therefore have a cooling effect. On the other, they impede the reflection of long-wave thermal radiation into space and thereby contribute to the natural greenhouse effect. Climate scientists have to parameterize the influence of clouds in the model, that is, describe all of the grid cells using approximations based on the mean effect of small-scale processes.

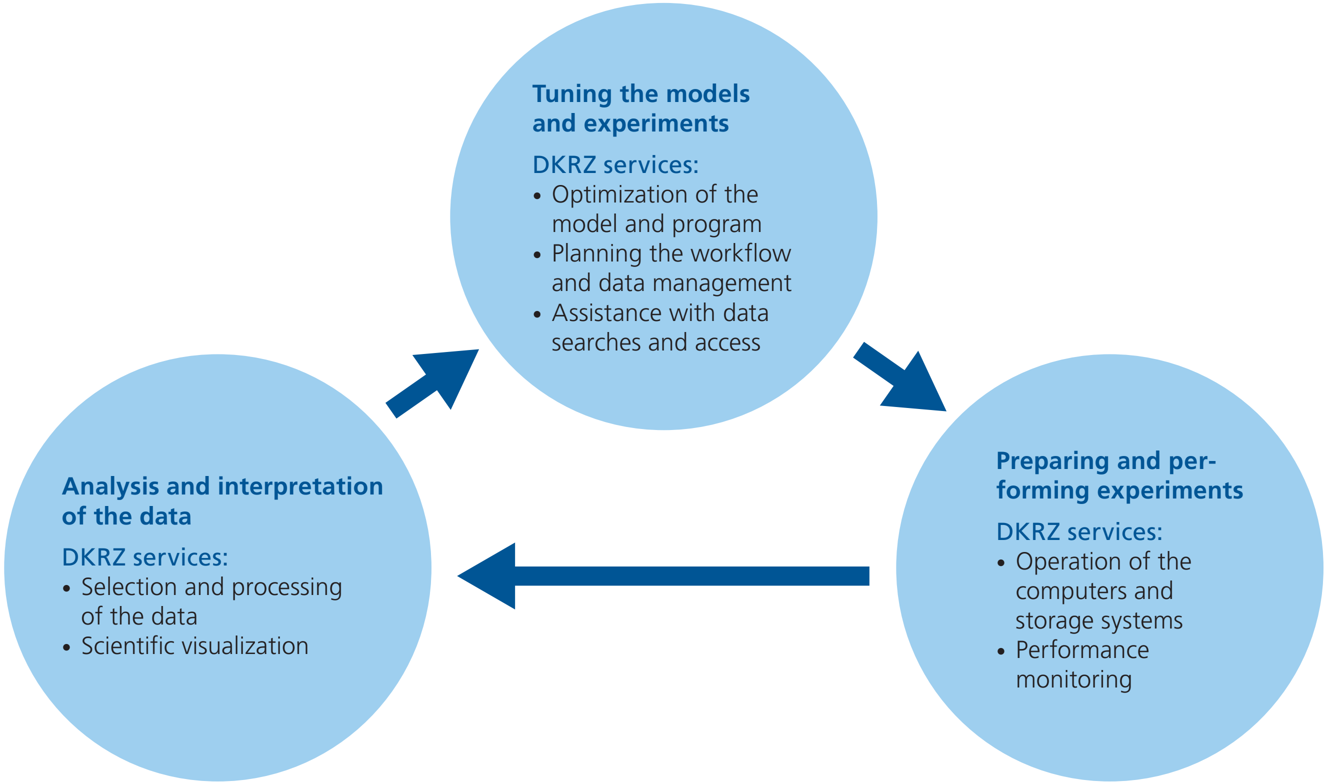
Computer systems and performance

The art of modeling

Science often begins with questions that thus far have not been answered, or not sufficiently so. To answer questions on climate, models and simulations are developed. DKRZ supports the researchers with technology and expertise at all stages of climate modeling.

Calculations as computer programs

The FORTRAN programming language is usually employed for climate modeling to transform the scientific calculations into a computer program. There are many ways to formulate these kinds of calculations in a program, but it does not run efficiently in all instances. Specialized extensions to this programming language enable the calculations to be accelerated on high-performance computers, with many of the numerical operations run in parallel. In addition, the programs must be optimized for the computer system used.



Many coincident steps are involved in developing the climate model, from adjusting the models, through preparation of experiments, to finally analyzing the data. DKRZ supports the scientists with its spectrum of services.

Experiments with a virtual Earth

If a model realistically simulates the most important processes in the climate system, scientists can run experiments with their numerical virtual Earth – that is, in the computer. For example, they can slowly change the chemical composition of the atmosphere in the model and thereby simulate the possible evolution of future atmospheric CO_2 concentrations. The results are stored at regular intervals, because the entire temporal evolution counts, not just the final state. The calculations and storage of the data must be exactly coordinated with each other in order to avoid data traffic jams and idle processor time.

Centerpiece of DKRZ: the supercomputer "Mistral"

The current high-performance computing system for Earth system research (HLRE-3) at DKRZ is named "Mistral" and consists of the computer itself, a hard-drive system as well as a high-bandwidth network. With almost ten times the performance, the first job for the initial configuration of the new machine will be taking over the tasks of its predecessor named "Blizzard" in summer 2015. In its final stage of expansion, Mistral will double its computing capacity yet again (summer 2016) and attain a peak performance of 3 petaFLOPS. With about 3,000 computing nodes and more than 68,000 processor cores as well as a 50-petabyte parallel file system, it will for example enable regional climate simulations to be carried out and evaluated at considerably higher resolution. More processes can be taken into account in the Earth system models as well, and uncertainties reduced in climate projections.

With the second stage of expansion in 2016, Mistral consists of ten such rows of computer racks – part of the hard-drive system (left) and the computational nodes (right) can be seen in the image above.

Short pathways

In addition to the computing nodes, Mistral provides 24 high end visualization nodes equipped with powerful graphics processors and a hundred further nodes for the pre- and post-processing and analysis of the data. The advantage of the system: all of the components are connected with one another via optical cables and can therefore access the shared file system fast and directly. The results of the modeling calculated on the supercomputer can be directly analyzed on the data visualization nodes.

Experts in modeling and parallel programming

DKRZ's in-house scientists work alongside the climate scientists, advising them on the optimum utilization of valuable computer resources. They offer a range of services covering modeling and programming, from support in carrying out climate simulations, through parallelization and optimization of the simulation programs, to analysis and visualization of the simulation results.

First-class climate simulations

Scientists modeling climate use a considerable portion of DKRZ computing capability for comprehensive simulations as part of international research initiatives and model intercomparison projects. DKRZ supports these research teams with IT-resources as well as in-house experts. The resulting calculations can be used by all researchers free of charge. Many of these results go into the regular reports of the Intergovernmental Panel on Climate Change (IPCC). The German contribution to these prestigious international efforts originates predominantly from the supercomputers at DKRZ – and challenges the resources of DKRZ systems to the extreme.

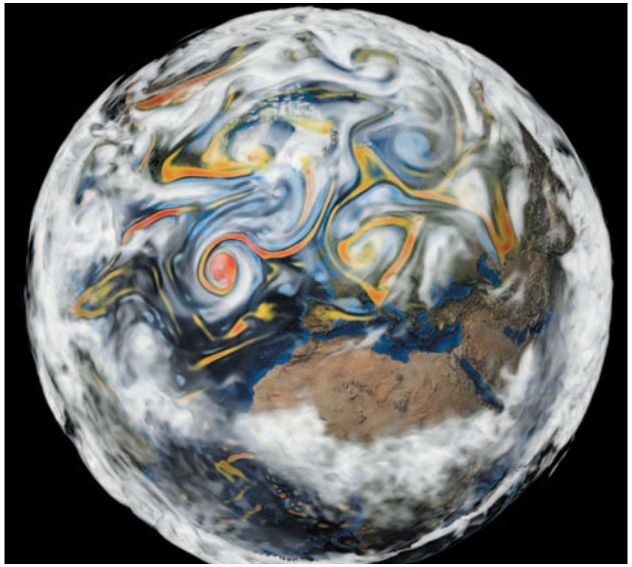
Tailored supercomputers

State-of-the-art technology tailored to the needs of climate and climate impact research – there are few comparable computer systems globally and none configured exactly like the DKRZ system. The DKRZ staff are well-versed in its specialized properties in order to make best use of its performance. This benefits DKRZ users through optimization of their programs, for example. In addition, DKRZ specialists adapt the climate simulation programs to the increasingly parallel operation of the computer system – while the first DKRZ computer had only one processor 25 years ago, today more than 68,000 processor cores calculate simultaneously in parallel.

Climate data in 3D

However, what do the extensive data from the climate simulations ultimately tell us? A key technology for understanding and communicating the results is scientific visualization. This allows the climate data to be transformed into dynamic 3D images, because the typical data sets produced by climate models are three-dimensional, time-dependent, and comprise many climate variables at once. Interactive visual data analysis can accelerate comprehension of the enormous quantity of data on the one hand. On the other, researchers can use this kind of visual presentation for lectures and publications about their scientific findings.

The DKRZ supercomputer system doesn't just produce enormous quantities of data, it makes these data visually comprehensible. Software specifically for visualization of climate data reads the specialized data formats from climate simulations and wraps the visual representation conveniently around a 3D Earth. A special service of DKRZ: the finished images land right at the researchers' workstations. Climate data at DKRZ can even be visualized interactively in 3D virtual reality.



This high-resolution climate model shows the cloud cover and vortex strength.

Explosion of FLOPS and bytes: computing performance and progress in science

1985: Control Data Cyber 205

- 1 processor
- 0.2 gigaFLOPS
- 0.032 gigabyte main memory
- 2.5 gigabyte hard-drive system

1988: Cray 2S

- 4 processors
- 2 gigaFLOPS
- 1 gigabyte main memory
- 25 gigabyte hard-drive system
- 1.2 terabyte magnetic tape archive

1994: Cray C-916

- 16 processors
- 16 gigaFLOPS
- 2 gigabyte main memory + 4 gigabyte ram disk
- 128 gigabyte hard-drive system
- 10 terabyte magnetic tape archive

1985

- Simulations with 3D atmosphere and ocean models
- Development of coupled models: 3D atmosphere und mixed-layer ocean
- Resultant data: 4 gigabytes
- Simulated period: months to years
- Grid interval for the atmosphere: 500 km

1990

- Simulations with a coupled 3D atmosphere/ocean model
- Experiment with doubling of CO_2
- First simulations with continuous rise of CO_2
- Resultant data: 80 gigabytes
- Simulated period: 200 years
- Grid interval: 500 km

1995

- Simulations with various scenarios of evolving atmospheric CO_2 concentrations
- First regional models
- Resultant data: 1 terabyte
- Simulated period: several hundred years
- Grid interval: 500–250 km

The computing capability at DKRZ has increased enormously over the past decades. This enabled considerable progress to be made in climate modeling. While the first DKRZ computers only allowed either the atmosphere or the ocean to be simulated, today there are many additional processes incorporated, such as the carbon cycle. Additionally, every new computer system facilitated expansion of the simulated time spans and higher spatial resolutions through the continually finer grid intervals. The simulations thereby draw ever closer to reality. Simulations cannot duplicate reality in its infinite detail, since even the most powerful climate computers in the world will hit finite performance barriers, and the underlying models are always a simplification of reality. However, climate simulations do not need to duplicate reality to accurately predict it.

2002: NEC SX-6 named "Hurrikan"

- 192 processors
- 1.5 teraFLOPS
- 1.5 terabyte main memory
- 60 terabyte hard-drive system
- 3.4 petabyte magnetic tape archive

2009: IBM Power6 named "Blizzard"

- 8,448 processors
- 158 teraFLOPS
- 20 terabyte main memory
- 6 petabyte hard-drive system
- 60 petabyte magnetic tape archive

2015/2016: Bull/Atos bullx B700 DLC named "Mistral"

- 36,000/68,000 processors
- 1.4/3 petaFLOPS
- 120/240 terabyte main memory
- 20/50 petabyte hard-drive system
- up to 500 petabyte magnetic tape archive

2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015

2004

- Aerosols accounted for in the atmosphere
- First hydrologic model of land masses
- Resultant data: 150 terabytes
- Simulated period: 5,000 years
- Grid interval: 180 km

2010

- Emulation of the carbon cycle including the biosphere and oceanic bio-geochemistry
- Ensemble simulations
- Resultant data: 1 petabyte
- Simulated period: 10,000 years
- Grid interval: 180–50 km

2015

- Regional model able to resolve clouds for Germany with 25 billion grid cells
- Resultant data: between 1 and 20 petabytes
- Simulated period: between months and 100,000 years
- Grid interval of global models: 40 km (atmosphere), 10 km (oceans)

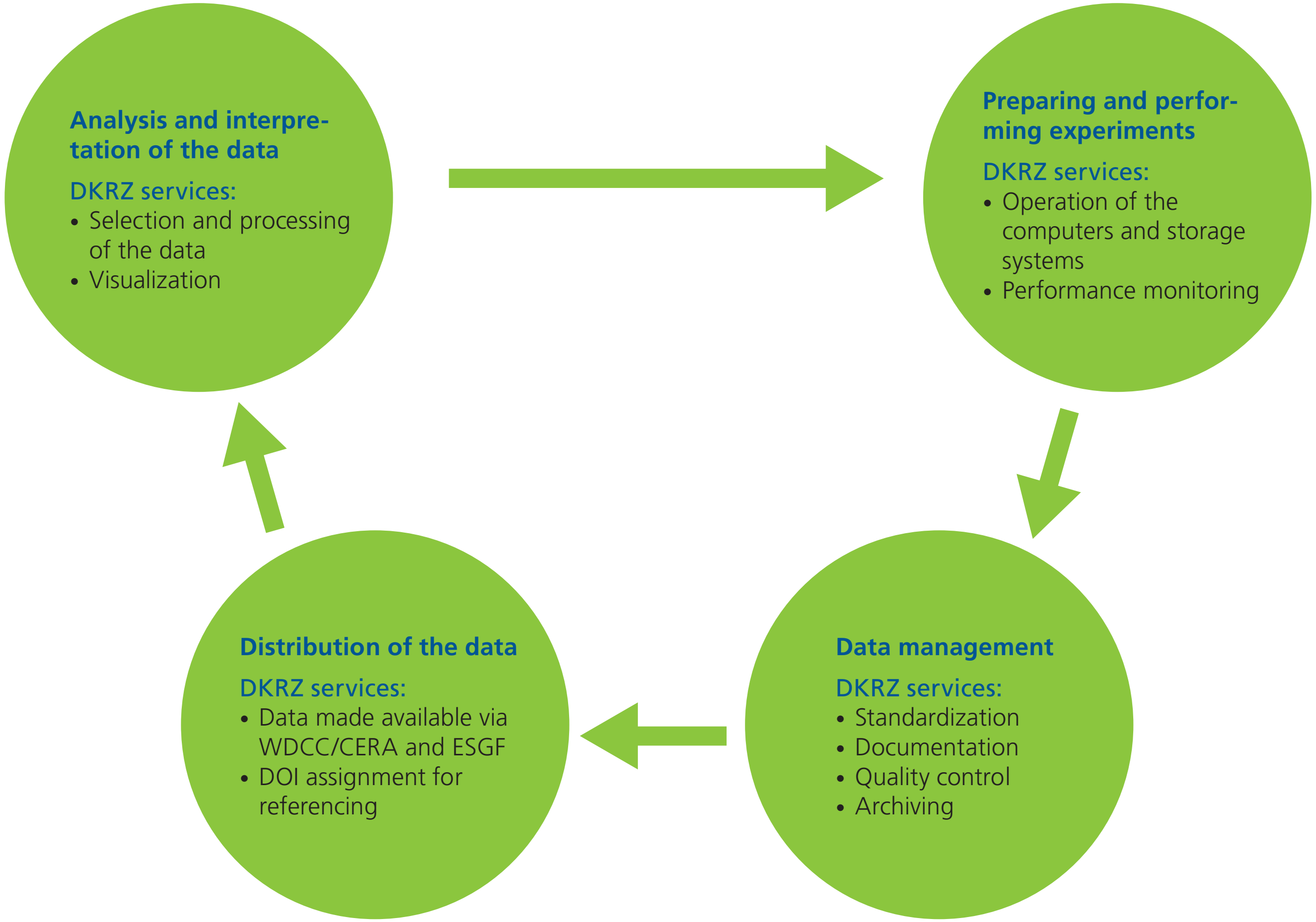
Petabyte Data Storage and Data Services

Producing enormous quantities of data

Once climate researchers have developed a model Earth that reproduces our climate events well, they carry out climate experiments on the model Earth in the computer – and produce data. DKRZ experts help them to identify and prepare the input data necessary for the experiments as well as planning the data and information flows. This involves coordinating everything within the specific environment of the high performance computer system. The supercomputer, hard-drive storage, and archiving system need to work hand-in-hand so that the work flow of producing the data does not stall.

Demanding requirements

For longer climate simulations, the data management is synchronized with the calculation of the data. The data undergo a quality check and standardization before being archived. To remain available for later use – sometimes years after conclusion of the research project, and by scientists who were not participants – the data need to meet special requirements. For example, they are tagged with what are referred to as meta-data that describe the contents of each of the data files. Data archived for the long term that remain unchanged are published and receive a specific data allocation tag called the digital object identifier, or DOI. Just as books can be referenced by an international standard book number (ISBN), these data can then be uniquely referred to by the DOI. Climate data bases and gateways finally distribute the data through the web to the users. Many of the data from the climate simulation experiments are also visualized, in other words translated into images.



Data production comprises the preparation and execution of experiments, the data management, the distribution as well as the analysis of the data. DKRZ offers its users numerous services and helps optimize the data flows. (WDCC: World Data Climate Center, CERA: Climate and Environmental Data Retrieval and Archive of the WDCC, ESGF: Earth System Grid Federation)

The DKRZ treasury: its data archive

DKRZ operates one of the world's largest repositories of data. The archive encompasses more than 40 petabytes of data generated from climate simulations spread over 20 million data files at the beginning of 2015. For purposes of comparison, an average-length film of about two hours stored on a Hollywood DVD represents about 5 gigabytes of data. Converting this, 40 petabytes therefore represents eight million movies comprising about 1,800 years of full-length films.

Ultrafast transfer

The data reside in eight automatic tape libraries on a total of 77,000 magnetic tape cartridges. The High Performance Storage System (HPSS) software administrates all the data and acts as a central data entry and access interface for the magnetic tape archives. With an expansion of the storage system in 2015, scientists can now transfer their climate data between the high-performance computer and the archive system at a rate of 18 gigabytes per second. Eight robotic arms in each library extract the requested cassettes and bring them to a total of 65 tape drives, where the data are either written onto the cartridges or read from them. The memory buffer required for this – the hard-drive cache – is 5 petabytes that by itself corresponds to the storage capacity of 5,000 well-equipped laptops.

Vigorous growth

Mistral, the new DKRZ high-performance computer, is able to produce so much data that the archive will experience vigorous growth, estimated at about 75 petabytes per year. Technically, it can host about 500 petabytes of climate data by 2020.

The treasure of data on the magnetic tape cartridges is extremely well protected. Reduction of oxygen in the data archive prevents fires. Additionally, DKRZ stores duplicates of the most important data at two different sites.

Valuable services for the climatologists' treasure

Generation, storage, evaluation, archiving, distribution and visualization – DKRZ supports the entire life cycle of the climate model data with its specialized services. The World Data Center for Climate (WDCC) hosted at DKRZ offers scientists long-term archiving of their resultant data. Scientists can also search the large store of data as well as the comprehensive results of large joint research projects according to specific search criteria via the web. In this way, they can acquire the ideal baseline data for specific scientific questions. The technical backbone for this is the Climate and Environmental Data Retrieval and Archive (CERA) system. Its search engine can be used to locate data sets corresponding to the desired criteria such as time interval and resolution. The researchers can then download and analyze the data set that has been located.

DKRZ participates in the international Earth System Grid Federation (ESGF), a data infrastructure with data nodes in Europe, the USA, Canada, China, Japan, and Australia. The various archives store data obtained through comparative experiments of global and regional climate models as well as from comparisons with observational data.

Pivot point for international projects

DKRZ is one of few centers globally that plays a dual role for the World Climate Report. Besides acting as a data node, it also acts as a gateway so that scientists can acquire globally distributed data. DKRZ also carries out what are referred to as consortium calculations for national and international joint projects that are of interest for a larger community. DKRZ staff prepares the data so that the researchers can easily use them.

A question of data management

The scientists are able to store their data during their projects on magnetic tape in the long-term data archive at DKRZ for at least ten years and have them available for third parties. The DKRZ data managers add additional information to the data – the metadata and DOI numbers for reference – and integrate them into the CERA climate databank.

DKRZ is also maintaining a web portal under the IS-ENES project of the European Network for Earth System Modeling (ENES), encompassing both the information and access ports for the European Earth system models. In addition, DKRZ is analyzing climate models with respect to future computer architectures.

Researchers choosing DKRZ services (2014 data)

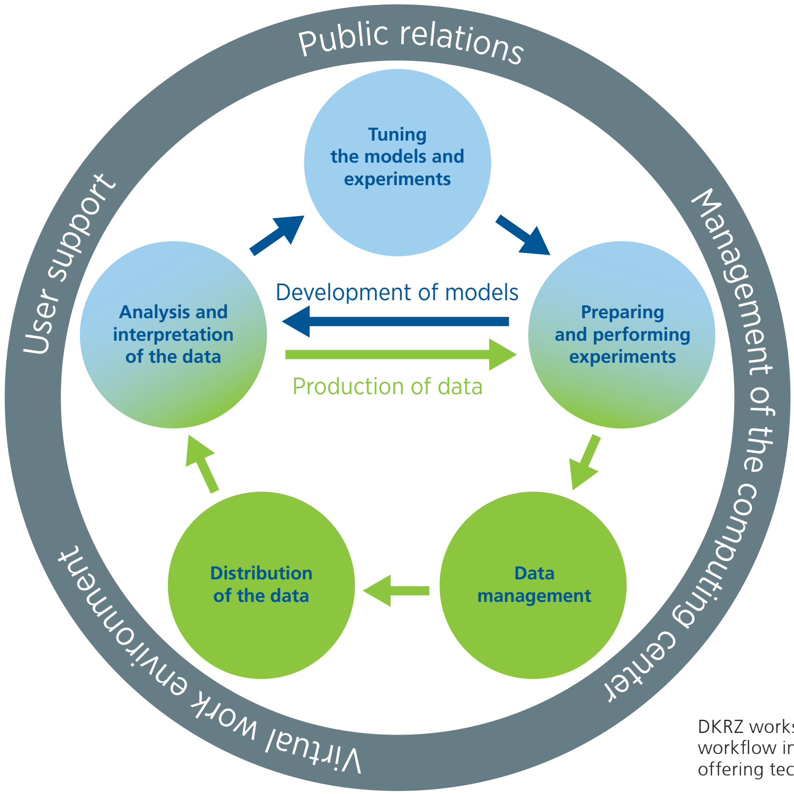
- 5,743 scientists used WDCC services.
- The CERA climate data base grew to 4,033 terabytes.
- CERA data base accessed 205,000 per month on average.

Service and Research

Assistance for working effectively and efficiently

Climate researchers are in the best of hands at DKRZ. In addition to the continuous preventative maintenance and regular updating of the system, the staff at DKRZ is passionate about making the scientists' work in this virtual Earth system laboratory easier. Thanks to the availability of specialized technical consulting, training, and in-house courses, the users can effectively and more efficiently employ the computer resources for developing and improving their climate models.

Specialists from DKRZ and other institutions meet with users in workshops to determine optimized approaches for their climate modeling applications. DKRZ experts also train users in developing complex parallelized computer programs – specially for the computer architectures employed. In addition, how to deal with the data is important: in order to publish the data and make them re-useable, data tags known as meta-data for documenting the climate data need to be stored. Moreover, the users learn various data visualization techniques in workshops.



DKRZ works closely with its users on all aspects of the workflow in developing models and producing data, offering technical advice and many other services.

Virtual work environment

The quantities of data in climate research today are so huge that they do not really fit on individual workstation machines. To overcome this problem, DKRZ offers its users powerful virtual work environments via cloud services and integrates specially configured project servers in the computing center for users.

DKRZ has also implemented specialized scientific virtual data networks in conjunction with other institutions over the past years. DKRZ advises institutes studying climate impact and guides them as they enter into virtual climate data collaborations. New concepts for long-term archiving and shared use of scientific data have likewise arisen. A guide and check list developed at DKRZ helps to establish research data archives today. The practical usability was also improved. The specialized data formats used in climate research can also be converted into formats that common computer software can work with.

Environmentally aware, more energy-efficient and reliable

DKRZ is improving the methods used in high-performance computing and data management through its own research. The discrepancy between the maximum theoretical performance of the computer and the actual computational speed attained with climate models has grown with each new generation of computers. For this reason, DKRZ is conducting research on new programming concepts in order to better exploit the performance of the computer. Optimized computer programs also consume less electrical energy.

DKRZ likewise participates in research projects that deal with efficient and reliable management of large quantities of data. As an example, specialized methods and infrastructure are being developed in collaboration with other scientific institutions for the entire life cycle of diverse quantities of data through the Large-Scale Data Management and Analysis (LSDMA) project. Inter-institutional data lifecycle labs are being formed as well as a data service integration team for developing and making available technologies covering administration, access, security, storage, and archiving of data.

Fans are installed on the roof of DKRZ. They expel the heat produced by the computer to the outside.

Taking responsibility and living it: green computer center

High-performance computing consumes a lot of electrical power – and electrical power today still means CO_2 generation. There is no doubt about it: DKRZ as a climate computing center takes its responsibility for the environment very seriously and is committed not just to maximizing computational performance, but also to minimizing its energy consumption. Mistral, the new supercomputer, is a real powerhouse at 3 petaFLOPS peak performance, but also exemplary in its energy efficiency. Despite a 20-times increase in performance compared to its predecessor, Mistral consumes the same amount of electrical power.

The computer system is warm-water-cooled. The heat is immediately dissipated right where it is generated – at the processor and main memory modules. These are less sensitive to heat than older systems. This allows the cooling liquid to become hot enough that it can release its heat from the roof of the DKRZ building throughout the entire year. So no electrical cooling is needed – which saves energy. The operating and maintenance costs for air conditioning the computer system are therefore sharply lower. In addition, DKRZ makes another contribution to climate protection. It draws its power from renewable energy sources.

Climate research you can touch

DKRZ does not just facilitate leading climate research, it also informs the public, the media, politicians, and experts about new findings in climate research and its in-house services. Around a thousand visitors come each year, including many school children interested in climate change, climate simulations, and supercomputers. Pupils can get to know what being a climate scientist is like on Green Day and Girls' Day.

DKRZ staff offer the public tangible climate research during Hamburg's Climate Science Day, Science Night, the Extreme Weather Congress, and other events. Visitors are able to trace the possible effects of climate change on the climate globe or through 3D glasses. In addition, DKRZ supports exhibitions with visual materials such as Expo 2015 in Milan, Italy, and the Max Planck Society Science Tunnel.

A model for the common man

Since climate models are often puzzling for the average person, DKRZ assists with the preparation of a simplified climate model. This can be used on normal PCs by pupils, university students, and others that are interested in order to try out how increased concentrations of greenhouse gases influence climate, for example. Despite extensive simplifications, the results are basically comparable to those of complex climate models.

Publications for the general public give a cross section of the work at DKRZ and provide information about current activities and topics of interest. These include a commemorative volume from the 25th anniversary of the Center with an historical summary, the bi-annual yearbook, and the DKRZ Newsletters. DKRZ staff members are also sought-after speakers for radio, television, and newspapers.

DKRZ presents its work to professional audiences at national and international conferences like the International Supercomputing Conference and the annual general meeting of the European Geosciences Union. DKRZ staff additionally give regular lectures on climate research, high-performance computing, data management, and visualization techniques.

Visitors during Science Night 2013 in the Geomatikum at the University of Hamburg

Users and Projects

What are DKRZ users researching?

More than 1,500 scientists use the computers and services of DKRZ. Any climate researcher in Germany can apply for computer time. Calculations are also carried out for many research projects in collaboration with European and international scientists. A few examples:

MiKlip: predictions on scales of years to decades

Neither business, politics, nor society plan on scales of centuries, but instead for decades or years. They therefore need "medium-term climate predictions", abbreviated MiKlip in German. A system of models for these kinds of climate predictions is being set up in a program of the same name involving 23 German research institutes. DKRZ is the technological headquarters for the project. Researchers carry out global or regional climate simulations on the high-performance computer in order to study the influence of various processes on the predictability of climate for different regions. DKRZ also distributes the resulting data.

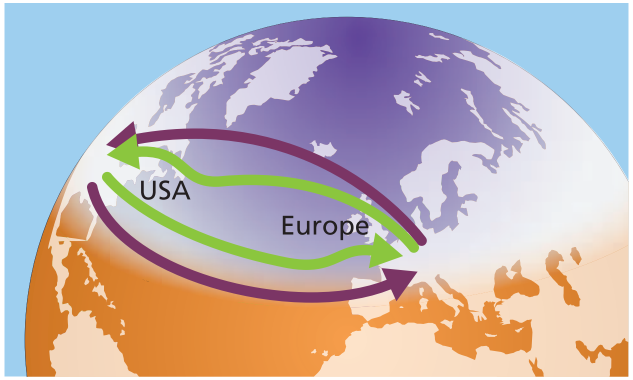
HD(CP)²: understanding clouds and precipitation

"High Definition Clouds and Precipitation for Advancing Climate Projections" is the complete name of the HD(CP)² project. Cloud and precipitation processes are being studied in the project to better understand their influence on the climate system, because they represent one of the largest sources of uncertainty in climate projections. Experimental and theoretical researchers are working closely with one another on this: an advanced model will simulate clouds and precipitation processes in very high resolution for Germany in order to compare them then with observational data. DKRZ is playing a central role in the modeling.

REACT4C: Climate optimized aviation routes

Air transport contributes to climate change through its emissions of carbon dioxide, nitrogen oxide, steam, carbon monoxide, uncombusted hydrocarbons as well as particles of exhaust soot that become aerosols. The international partners in the REACT4C project, including the European organization for air transport safety EUROCONTROL, have employed a combined climate-chemistry and flight-route model to study what changes to routes would be needed to reduce the influence of transatlantic flights on climate change.

The centerpiece of the study was the calculation of complicated climate cost functions – about two million processor hours of the DKRZ supercomputer Blizzard were used for the simulations. The results: by changing the flight path and altitude, the effects on climate of these flights can be reduced – tied to higher or lower additional operating costs depending on the magnitude of the climate optimization.



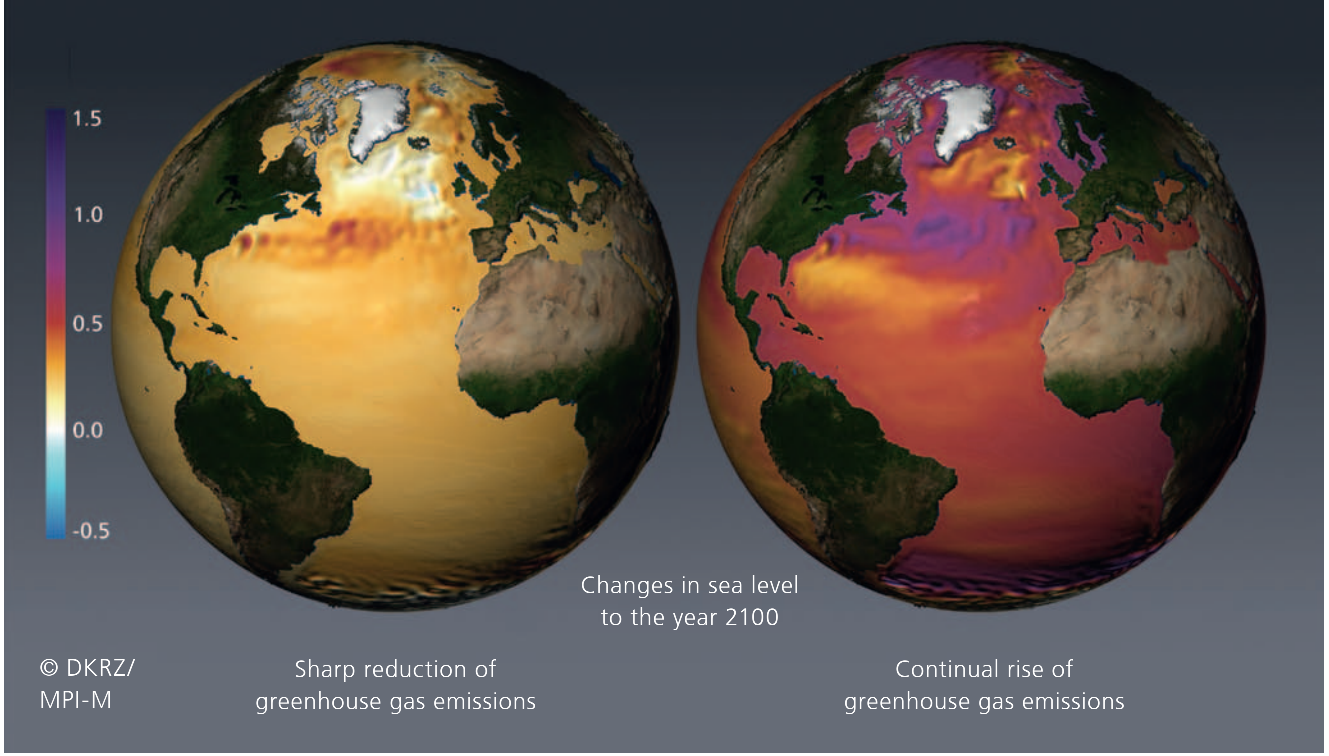
REACT4C: Flight path for air transport optimized for operating costs (purple arrow) and for climate effects (green arrow)

Simulations for the World Climate Reports

The Intergovernmental Panel on Climate Change (IPCC) periodically summarizes the state of climate research. Climate modelers around the world calculate standardized simulations in a comparative modeling effort called the Coupled Model Intercomparison Project (CMIP). The results can be evaluated and compared with one another in this way. 25 research teams from 19 countries with 58 different models participated in the CMIP Phase 5 project (CMIP5) for the 2013/2014 World Climate Report. They simulated the climate of the past from 1850 to 2005 and generated projections of the future climate up to the year 2300. The scientists employed scenarios of differing standardized increases of future greenhouse gas emissions for this. Moreover, the climate of the past 1,000 years was investigated and actual predictions were made for the first time covering the climate over the next ten years.

Germany's contribution

Climate modelers in Germany worked on this project as well. They performed calculations using the DKRZ computer with an Earth system model from the Max Planck Institute for Meteorology that also simulated the carbon cycle at the same time. The 350 climate experiments with their 13,000 model years absorbed one quarter of DKRZ supercomputing capacity over about a two-year period – for which normal notebook computers would have needed more than 1,000 years. DKRZ also played an important role in the international distribution of the CMIP5 data.



Sea level of the Atlantic Ocean and the polar seas will rise faster or slower over the coming decades depending on how the emissions of greenhouse gases change in the future (calculations using the Earth system model of the Max Planck Institute for Meteorology).

It's still not too late

The simulations showed that we still can achieve the two-degree goal. This assumes that we immediately and drastically reduce emissions of greenhouse gases. If the CO_2 concentrations climb further, however, not only will the temperatures change but other climate factors as well. For example, the oceans could rapidly acidify. That would drastically affect animals that form their shells with calcium.

The results of the global calculations also formed the baseline data for regional simulations. Using regional models, researchers calculated the climate for Africa and Europe – and still with a resolution of 12 to 50 kilometers.

Scientists, politicians, and other decision makers can access the most important data of the CMIP5 calculations through the world-wide Earth System Grid Federation (ESGF) and the World Data Center for Climate.

DKRZ and its partners

DKRZ is a non-profit corporation with four shareholders.

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DKRZ is an important partner in national, European, and international collaborations.

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