Summary of the Report

DKRZ 2000 +

Proposal for the Development of DKRZ into the next Century

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Summary

I. Responsibilities of the German Climate Computing Centre

Humanity is confronted today with the threat of a drastic change in global climate due to increasing emissions of greenhouse gases and other human activities. In order to develop effective climate-protection strategies, possible future climate changes and their consequences for society must be understood and quantified. This can be achieved only by means of complex model simulations using high-performance computer systems.

Reliable climate models must be based on detailed knowledge of the physical, chemical and biological processes which control the climate system. This requires also an understanding of natural climate variability, which is superimposed on the anthropogenic climate change signal over a broad range of time scales.

Natural and anthropogenic climate change, climate impact studies and climate protection strategies are closely interrelated and can be addressed successfully only through an integrated systems analysis approach.

The establishment of the German Climate Computing Centre (Deutsches Klimarechenzentrum, DKRZ) in 1987 as one of the few dedicated high-performance climate computing centres world-wide (together with the National Center for Atmospheric Research - NCAR - and the Geophysical Fluid Dynamics Laboratory - GFDL - in the USA, the Hadley Centre in Britain, and the French Centre Meteo-France) laid the foundation for effective climate research in Germany. The international standing of German climate research today can be attributed in large part to the computational work carried out at the DKRZ.

However, the German Climate Computing Centre faces considerably more difficult challenges in the last decade of this century than was the case at the time of its establishment eight years ago.

These result from

- **recent advances of climate modelling together with the increasing public awareness of the climate problem; these have created a strong demand for reliable predictions of future climate,**

which are urgently needed as a basis for policymaking, in particular with regard to the negotiation of international commitments for the reduction of CO_2 emissions within the framework of the Climate Convention (Berlin Mandate);

- **the related need to provide climate input data for climate impact studies,**

which require greatly increased spatial resolution of climate model simulations down to regional scales;

- **the substantial additional computing time required for climate impact research,**

  resulting in particular from the Berlin Mandate and the anticipated high costs of an effective climate protection strategy (the Enquête-Commission "Protection of the Atmosphere" of the Bundestag estimates Germany's share alone at 300 billion DM); this requires a major expansion of climate research into new fields;

- **the requirements of the international "Global Change" Programme,**

  of which climate research represents an essential element, and which will demand an extension of the present climate model hierarchy to the significantly more complex and computer-intensive areas of atmospheric chemistry, biogeochemical cycles, hydrology and ecology;

- **the increasing role of the DKRZ as a centre of expertise,**

  which follows from the evolving networking of climate research and the growing demand of external users for active participation in complex climate simulations carried out at DKRZ;

- **the concomitant increasing demand for high-performance computing resources by European research partners within the framework of the ECCN (European Climate Computer Network),**

  which arises through the reputation of the DKRZ as a European centre of expertise and which can be projected to expand if the DKRZ, with support from Hamburg's climate research institutes, continues to play a leading role in the European climate research community;

- **the rapid developments in the computer market,**

  particularly the forthcoming introduction of considerably more powerful moderately, highly or massively parallel computers, which will require support of a new programming paradigm and a stronger commitment of the DKRZ in the area of scientific computing,

- **the need for effective access to climate data,**

  particularly in support of the increasing number of users seeking simple and efficient access to the enormous quantities of data being produced by ever more powerful computer systems,

- **the need for efficient data communication lines**

  in order to connect an increasing number of clients more effectively to the DKRZ.

II. Consequences

Computer Performance

In order to meet these challenges, the computing power of DKRZ will need to be increased by at least two orders of magnitude within the next decade. This will become technically feasible through the development of new highly and massively parallel computers. The annual investments for the new computer generation are estimated to be of the order of 8-10 million DM (at today's costs). The high-performance compute-server used for large-scale simulations will need to be complemented by computer systems for data services, model development, model diagnostics and visualization, together with a high-speed communications network connecting the individual systems. These additional components, which are essential for an efficient utilization of the high-performance compute-server, will require an additional annual investment cost of 3-4 million DM. The operating costs of the computer system and the present level of services should require only a moderate increase compared to the present level of expenditures, which is of the order of 13 million DM. The enhancement of the data and model support services, together with the planned new scientific computing activities, could cost an additional 2-3 million DM per year. The total costs are high, but it must be realized that high-performance computers represent an indispensable tool for modern climate research - comparable to accelerators in particle physics or satellites in space research.

Although a trend towards a decentralization of computer resources can be observed in several research fields, in climate research the need for high-performance computers for carrying out complex simulations with high-resolution global climate models will, if any thing, increase in the foreseeable future. The future computer requirements in climate research will need to be met at three levels. The DKRZ facilities serve on the first level mainly as a powerful resource for elaborate large-scale simulations with high-resolution climate models, planned and carried out cooperatively by several institutes. A second level of computer systems, located in various climate research institutes, should be used for advanced simulations carried out at the individual institute level, while a third level of workstations should be used for the local processing of simulation results and the development of model components, algorithms, diagnostic software etc.

Global Change and Climate Impact Research

The incorporation of problems related to global change and climate impact within the scope of DKRZ responsibilities will automatically enlarge the field of DKRZ users. Because of the close interrelationship between research in climate and climate impact, the DKRZ would welcome the Potsdam Institute of Climate Impact Research (PIK) as a fifth shareholder. In order to enable PIK and other external research groups involved in these broadened research activities to use the DKRZ resources effectively, they should be connected to DKRZ via high-speed data links. The investments which have already been made in the national and European communication infrastructure could yield a far greater return for science through an appropriate financing policy for a scientific data network.

Evolution to a Service and Expertise Centre

By the turn of the century, DKRZ will have evolved from a computing centre with a primarily technical and operational orientation into a combined service and expertise centre. For the successful application of sophisticated climate models, consisting in general of a number of coupled complex subsystem models, climate researchers not directly engaged in model development must be advised by experts at DKRZ who are thoroughly acquainted with the models. The advisory role will gain in importance as DKRZ becomes more involved in the field of global change and with the increasing use of DKRZ by external research groups. In addition to providing general modelling support, the DKRZ user support group should also carry out routine modelling tasks, both to relieve basic research groups from these activities and to maintain the expertise of the group. These could include, for example, scenario computations of global greenhouse warming or model intercomparisons.

Scientific Computing Group at DKRZ

In the course of the evolution into a centre of expertise, a Scientific Computing Group should be established at DKRZ. Its principal task would be to test and implement algorithms and computing methods suitable for the coming generation of parallel computers and to assist users in the optimization of their models for the new parallel systems. Such an advisory service by a Scientific Computing Group familiar with new algorithms will be required also for future procurements of parallel computer systems selected to optimally satisfy the DKRZ needs.

Scientific Computing Network

The new DKRZ Scientific Computing Group will need to cooperate closely with similar groups at the Potsdam Institute for Climate Impact Research (PIK) and the Alfred-Wegener-Institute for Polar and Marine Research (AWI) in Bremerhaven. Work in this field should be coordinated through a Scientific Computing Network, in which, in addition to DKRZ, PIK and AWI, all institutes involved in climate and global change research would participate. Joint projects carried out within this network would be directed by scientific project coordinators reporting to the institutes involved in the project. Responsibilities would be divided between institutes and project coordinators in accordance with established matrix structures for such cooperative projects.

Joint Large-Scale Simulations

New forms of coordination need to be introduced at DKRZ in order to carry out extensive simulation experiments in the form of joint undertakings by a larger number of institutes. The increasing importance of such large joint simulations - also within the European context - requires organizational structures similar to those developed for experiments at high-energy particle-accelerator installations. The European Climate Computer Network (ECCN) and a proposed European Concerted Action Project "Cooperative Climate Simulation Experiments" may be regarded as first steps in this direction.

Institutional Structure

These developments demand reconsideration of the terms of reference, structure, and financing of DKRZ. The experience in the past has been good both with respect to the present institutionalized close interaction between the DKRZ and its supporting institutions, i.e. covering basic research and applications, and with respect to the legal status of the DKRZ as a limited corporation, jointly financed by the German Ministry of Education, Science, Research and Technology (BMBF) and the DKRZ shareholders.

This organizational structure was designed to meet the original responsibilities of DKRZ. It was largely oriented towards establishing an optimal balance between the diverse interests of the participating partners in basic and applied research. It had the great advantage during the initial evolution of the DKRZ of offering a high degree of flexibility. This would almost certainly not have been possible with other conventional institutional structures (e.g. "Blue List" Institute or Large Research Facility).

In considering the future organizational structure and financial security of the DKRZ, the positive experience gained with the present organizational and legal status should be kept in mind, especially with regard to the ability of reacting flexibly to new situations and the evolving, not necessarily parallel interests of the various DKRZ partners.

III. Relation to Problems of Global Climate and Environment

The costs for the DKRZ should be viewed in relation to the considerably greater national expenditures for modern climate and environmental research, including the international systems of earth-observing satellites and global observational networks. Without high- performance computers and complex models, the enormous flood of data provided by these systems cannot be effectively evaluated and interpreted.

The total expenditures for climate and environmental research are in turn infinitesimal compared with the price of adapting to global warming or of preventing or ameliorating climate change. This is of the order of hundreds of billions of DM. The far smaller expenditures for reliable climate and climate impact studies as input for the development of optimized climate-change prevention and adaptation strategies promise an exceptionally high return for investment. But a cost-benefit analysis hardly seems appropriate in this context. Humanity is confronted today with far-reaching decisions which will have an irreversible effect on the lives of all people. We cannot experiment with the earth, and it is too complex to be reproduced in the laboratory. The only available prognostic tool is the computer model. Climate model simulations are therefore indispensable if the impending far-reaching political decisions are to be founded on a rational scientific basis.

Although present-day climate models provide invaluable information regarding the expected future change in climate, the spatial resolution and physical-chemical-biological foundations of the models must be improved considerably in order to provide fully relevant data for detailed political planning purposes. In addition, extensive studies are required to clarify the interrelationships between climate change, climate change-impact and climate-protection strategies. As a leading industrial nation with a proclaimed vanguard role in climate-protection policy, and as host to the secretariat of the Berlin Mandate for establishing a climate-protection protocol, Germany should continue to provide the best available computational and technical conditions for climate model simulations on which political decisions will necessarily strongly depend.