MeteoSchweiz Forschungskolloquium 2011 – 2

Tuesday 29 November, 10:30 – 16:30

MeteoSwiss, Krähbühlstrasse 58, 8044 Zürich, Room 353 - 354

How much high performance computing does meteorology need?

Short Abstracts

2 Contribution of high performance computing to the evolution of meteorology in the last decade

Dominique Marbouty
ECMWF, United Kingdom

In this presentation, we will show the improvement over time of the quality of numerical weather predictions, emphasizing the impact on severe weather forecasts. We will then try to attribute this progress and evaluate the respective contributions of:

- development of the observing system
- improvement of the forecasting system (model and analysis)
- increase of computing performance

This will be based on reanalyses and specific experiments. The presentation will be based on ECMWF forecasting system and results. We will conclude with identifying the main challenges for future progress.

3 What is the expected added value of a further increase in resolution in the short to medium range forecast?

Humphrey Lean
Met Office, United Kingdom

I will describe Met Office experiences so far with convection permitting versions of the Unified model for short/medium term weather forecasting - in particular the "UKV" UK 1.5km model. I will show that, although these models produce significant benefits (both in case studies and in longer term statistics) problems still remain. In particular there are issues with the representation of convection resulting from it being under-resolved. Whilst we are working to resolve these problems, as far as possible, without reducing the gridlength of the model an increase in resolution might still turn out to the best option. I will show results from research models which already show benefits of going to resolutions significantly higher than 1.5km.

4 What is the expected added value of a further increase in resolution in climate science?

Bjorn Stevens
Max-Planck-Institut für Meteorologie, Germany

Clouds and convective processes remain the grand challenge of both climate science and numerical weather prediction (NWP). For climate science a representation of clouds, and their interaction with radiation, is crucial; while the distribution and character of precipitation has been difficult to represent with fidelity in either NWP or climate science. NWP systems, and to a lesser extent general circulation models, are routinely run at a resolution of a few kilometers, which while capable of resolving deep convective systems, requires advanced parameterizations to couple such systems to the boundary layer, and the surface. The next leap, a great leap, to sub kilometer resolution will jump over this Terra Incognita of near convective scales and provide clues as to whether the interplay between clouds, convection and large-scale dynamics is determinant, or whether yet smaller scale processes, such as cloud microphysical processes, exert an important control on atmospheric circulations.

5 Towards cloud-resolving climate modeling

Christoph Schär
ETH Zurich, Switzerland
Center for Climate Systems Modeling (C2SM), Switzerland

The provision of accurate projections of future climate is crucial for our society. Yet, large uncertainties remain for global and regional climate change projections. It is generally accepted that the inability of current climate models to represent organized convection is a major source of uncertainty. Even for global indicators, such as global climate sensitivity, cloud feedbacks are the largest source of inter-model differences. In terms of regional projections, these associated uncertainties are particularly relevant for the representation of the hydrological cycle and extreme events.

In this presentation we will discuss the use of cloud-resolving atmospheric models in climate change studies. Specific issues to be addressed include process studies of moist convection, the convergence of climate models, and the use of cloud-resolving models in climate scenario simulations. Selected results will be presented from long-term cloud-resolving simulations over the Alpine region. We will also address the associated computational needs and implications for high-performance computing systems.

6 Higher resolution vs. ensemble forecasting

Bodo Ritter
DWD, Germany

Numerical weather prediction constitutes a computational problem which presents a severe challenge for even the most advanced high performance hardware and for the developers of the NWP model itself. As a consequence of constraints imposed by the available resources compromises are sought which seek to optimize the use of current and future hardware. In any national meteorological services

this optimization obviously must take into account the basic objective to provide state-of-the-art high quality weather forecasts. This objective has to be achieved within additional constraints imposed by factors like limitations with regard to scientific knowledge, availability of human resources and conflicts of interest within the diverse potential applications of NWP models.
At DWD the traditional striving for ever improving classical skill scores of deterministic NWP has recently been complemented by the introduction of the ensemble approach as a means to quantify the uncertainty of any prediction. As very short range forecasts of severe weather are in the focus of DWD's interests, the ensemble systems developed at DWD are primarily developed for very high resolution NWP applications.
The presentation will provide insight in the arguments underlying DWD's decision to devote a major share of its computational resources to the ensemble approach and aim for only moderate improvements in model resolution at the same time.

7 The importance of high performance computing for post-processing

Thordis Thorarinsdottir
Heidelberg University, Germany

Even though the predictive performance of ensemble forecasts has improved significantly in the last decade, statistical post-processing is often called for to correct for possible bias and incorrect representation of the uncertainty in the forecast. Established post-processing approaches are developed for single weather variables at single look-ahead times and only few selected methods take the underlying structure of the spatial domain into account. These methods usually require very short computation times compared to the computation time needed for the original ensemble forecast. However, while such post-processing methods improve the predictive performance of the ensemble, the multivariate correlation structure is often lost in the process. The main focus of current research is thus to develop post-processing methods that return physically consistent calibrated multivariate forecasts of spatio-temporal trajectories and such methods will require substantially longer computation times.

8 Future role of high performance computing in the advancement of science

Thomas Schulthess
CSCS, Switzerland

Simulations have evolved into an important pillar of modern scientific investigations of complex systems, and the continued exponential increase in computer performance will undoubtedly broaden the range of solvable problems. However, the excessive power consumption of modern computing systems is changing the character of high-performance computing. The traditional distinction between capability and capacity computing is no longer relevant, and a trend emerges where application codes, numerical libraries, and computing systems are co-designed. We will discuss these developments and their implication on the nature of simulations based sciences in the future. In particular, we will elucidate options for future climate and meteorological simulations.

9 How MeteoSwiss is preparing for future HPC architectures

Oliver Fuhrer
MeteoSwiss, Switzerland

The available computer power is the most important constraint limiting the horizontal resolution, the complexity of the model system, and the number of ensemble members of numerical weather prediction and climate models. Emerging and future supercomputing architectures are expected to bring several changes: an increasing number of compute cores competing for resources such as memory bandwidth and communication bandwidth, only slow increases of the throughput of I/O sub-systems, heterogenous computes nodes with accelerators such as GPUs.

In order to leverage future supercomputers current weather prediction codes have to be adapted. To this end, the HP2C COSMO and HP2C OPCODE projects carried out in the framework of the Swiss HP2C (High Performance High Productivity Computing) initiative aims at re-engineering the numerical weather prediction and regional climate model COSMO (Consortium of Small-Scale Modelling) with the aim to run efficiently on both massively parallel scalar machines as well as heterogeneous systems with GPUs (Graphical Processor Units). The project encompasses a redesign of the model code in order to use memory bandwidth more efficiently, have the capability to run the same code on CPUs and GPUs, and improve the I/O strategy.