With a constantly changing natural environment, LMU's Professor Dr Dieter Kranzlmüller discusses how computing models can provide key benefits in an uncertain landscape

The 'grand challenge'

Nature can be characterised as consisting of several, highly interconnected systems with intrasystem and intersystem feedback loops. Accurate modelling of even a single system can be a challenging undertaking, not to mention a system of systems. The results of long-term simulations can often be dependent on minor variations in the measurements describing the initial conditions, as illustrated by the so-called 'butterfly effect' metaphor ('a single beat of a butterfly's wing can cause a tornado thousands of kilometres away').

Despite these 'natural' limitations and the pitfalls of environmental models, there is a growing need to model individual systems and their interactions more and more accurately. Climate change adaptation, disaster risk reduction, etc. necessitate not only predicting the behaviour of specific systems, but their combined impact on environment, society and economy. For example, predicting the changes in future rain patterns is an interesting research question and useful input for different planning activities.

Yet in order for these planning activities to support decision making efficiently, they need to put these changes in an individual system into the context of rising sea levels and changes in the absorption capacity of the ground, which in turn depends on changes in natural vegetation and in human activity (agriculture, urban development, etc.). To be actionable, the generated knowledge must enable assessment of the impact of the phenomena to be studied in the context of other issues requiring attention.

On demand

The central challenge environmental computing aims to address can be seen as finding a balance between the inherent limitations of the individual models and the requirement to provide support for on-demand decision making, based on multidata, multimodel simulations that need work on different scales. From a technology perspective, this demands automating complex multimodel workflows and promoting common data exchange and visualisation standards.

One of the major drivers in this development is the recent 'Sendai Framework for Disaster Risk Reduction' that brings ambitious goals in terms of preparing for natural hazards and minimising the risks to the population and infrastructure to all UN member states.

Computational modelling is crucial. Today's limitations of the modelling approaches are typically addressed through probabilistic approaches, executing several simulations with slightly different parameters to allow probabilistic analysis of the results. A variant of this approach – ensemble forecasting – uses more than one model solution in parallel to analyse the same data and thus helps to identify situations where there is considerable difference in the results of the different modelling approaches.

Professor Dr Dieter Kranzlmüller

Transdisciplinary target

Despite recent advances in modelling approaches and corresponding technologies, the vision of on-demand support for decision making is still out of reach for many domains. In situations where immediate action is needed – for example, to address potential natural disasters – it would be necessary to harness all available computing resources for such urgent modelling tasks. However, rapid division of computational tasks and data to be processed across different hardware and software architectures is still an area of active research within the 'urgent computing' discipline.

More importantly, today there are no easy, generalised ways to deduct and present the degree of confidence in the results of aggregate models. Even if the probabilistic and ensemble approaches protect against anomalies in the behaviour of individual models, predicting detailed local trends based on global models may introduce fundamental errors already in the input stage of the local model.

These issues are addressed by several distinct communities formed around discipline-based organisations and collaborations. While this made considerable advances in modelling specific phenomena possible – for example, the reliable prediction of extreme heat waves much earlier than 20 years ago – a transdisciplinary approach for the generation of actionable knowledge related to interlinked natural phenomena using an arbitrary set of trusted models and data sources is still beyond the current state-of-the-art. Identifying, describing and interconnecting these trusted models and data sources is going to be the next 'grand challenge' in the field of environmental computing.

Professor Dr Dieter Kranzlmüller
Director
Leibniz Supercomputing Centre
Ludwig-Maximilians-Universität Munich

www.mnm-team.org