Presentations at the World Modelling Summit for Climate Predictions

6-9 May 2008

Jagadish Shukla (GMU/COLA)

Revolutionizing climate prediction: a real need and a real possibility

There is considerable historical evidence that major scientific and technical discoveries are often followed by the creation of institutions that can take advantage of those discoveries for the betterment of society. The breakthrough in our understanding of atmospheric dynamics that was developed during and after the Second World War, accompanied by the technological breakthrough of fast automatic computing devices, led to the rapid development of numerical weather prediction, a capability that has been institutionalized by many governments around the world and commercialized into a multi-billion Euro enterprise worldwide. The European Centre for Medium-Range Weather Forecasts is but one example, albeit a glorious one.

A second example is the development of our scientific understanding of chaos in nonlinear dynamical systems and the potential for predictability at seasonal time scales in the midst of that chaos. The application of that capability for seasonal climate prediction led to the creation of the International Research Institute for Climate and Society.

Now we have before us, thanks to IPCC, a third discovery: humans are affecting the Earth's climate. Beyond IPCC, this discovery will inevitably lead to the establishment of new institutions, or a transformation of current institutions, whose goal will be to help the peoples, governments and corporations of the world manage the consequences of climate change wisely, economically and effectively. This meeting is one step in that direction. The purpose of this meeting is to develop a visionary strategy to revolutionize climate prediction.

Society needs reliable predictions of changes in the statistics of regional climate to develop appropriate adaptation and mitigation strategies. Significant enhancement of the scientific workforce and computing resources is essential to advance our predictive understanding of the climate system, and to provide more reliable estimates of regional climate variations. The current generation high-end computers for climate research have a capability of about 50 teraflops, which makes it possible to integrate a typical climate model with about 100 km horizontal resolution for 20 years in one day. We must be able to run climate models at the same resolution as weather prediction models, which may have horizontal resolutions of 3-5 km within the next 5 years. This will require computers with peak capability of about 100 petaflops.

It is imperative that the summit recommends a realistic roadmap to enable and accelerate progress in climate modelling and prediction and to provide substantial and sustained support for enhanced workforce and computing resources. This is our moment! The problem of climate change has riveted the attention of the peoples of the Earth.

Michel Jarraud (WMO)

Reducing the risk associated with climate variability and change and severe weather through enhanced prediction – the need for international cooperation

As a specialized agency of the United Nations System, the World Meteorological Organization (WMO) provides the authoritative voice on the state and behaviour of the Earth's atmosphere, its interaction with the oceans, the climate it produces and the resulting distribution of water resources to the National Meteorological and Hydrological Services (NMHSs) of its 188 Members.

Exceptional progress in numerical weather prediction over the last 50 years has led to major achievements which today underpin the WMO operational production of global and regional weather forecasts. For this to be possible, two essential elements have been WMO's coordinated Global Observing System (GOS), which is maintained by the NMHSs and provides real-time global environmental observations, and the WMO Global Telecommunication System (GTS), to exchange these observations, products and services. During the next decade, as the GOS and GTS evolve into the WMO Integrated Global Observing System (WIGOS) and WMO Information System (WIS), respectively, a key challenge for the climate and weather communities will be to ensure that an analogous system is developed for climate prediction.

Through its World Weather Research Programme (WWRP), as well as in partnership with other organizations co-sponsoring the World Climate Research Programme (WCRP), WMO increasingly collaborates with other disciplines. New partnerships are being consolidated by sharing knowledge and expertise, but also through a common awareness of the critical societal importance of research intended to overcome barriers still limiting our skills in weather and climate modelling. It is however necessary to foster the development and improvement of a continuum of numerical prediction systems, ranging from short-term weather forecasting to longer-term climate predictions. Therefore, the present conference comes at an opportune time to contribute in developing or further strengthening these vital partnerships.

WMO has distinctly recognized that an enhanced international prediction framework will be required to address the needs of climate change adaptation and to reduce the risks related to more frequent or more intense severe weather in a world with an increasingly vulnerable population. In August 2009, climate prediction on the seasonal, inter-seasonal and decadal time scales will be a key focus of the high-level World Climate Conference - 3 (WCC-3), organized by WMO in Geneva to meet, in particular, the vital needs of decision-makers. The outcome of this summit will undoubtedly provide a key contribution to the WCC-3.

Jeffrey Sachs (Earth Institute)

The effects of climate change on international migration, trade, and the distribution of income

Future climate change will have highly diverse effects on the world's major regions, and consequently are likely to cause large-scale changes in patterns of migration, trade, and production. Global models of inter-regional migration, trade and production have yet to be implemented, in part because the underlying climatology at a regional scale remains highly uncertain. Nonetheless, it is useful to speculate on the inter-regional pressures that will be caused by global climate change, and on the implications for public policy regarding climate change mitigation and adaptation.

Chris Llewellyn-Smith (UKAEA)

Lessons from ITER and CERN*
*(*for proponents of an International Multi-Petaflop Computing Facility dedicated to high resolution climate change modelling)*

The case for an International Multi-Petaflop Computing Facility dedicated to high resolution climate change modelling looks compelling. The challenges will be to obtain agreement and funding, and set it up without undue delay, and to ensure that it can operate effectively. After some brief words on the status of fusion and the need for ITER (as agreed with Tim Palmer as the price for speaking), I will make some very brief remarks on supercomputing in fusion. Issues to be addressed in setting up an International Computing Facility include: identifying an umbrella organisation, what body should represent Europe, the contribution of the Host, choosing a site, whether to build on a green-field site, the basis of contributions, and scientific and political governance. Experience with ITER suggests that setting up the proposed international Multi-Petaflop Computing Facility will not be easy, and one lesson from CERN and ITER is that it will take time. It should however be possible to profit from the ITER and CERN experiences to speed things up. With goodwill there should/must be a way to do it - and do it quickly. Good luck!

Brian Hoskins (Reading University)

The development of the 2005015 WCRP Strategic Framework

Some of the ideas on directions for climate modelling that emerged in the development of the WCRP Strategic Framework (COPES) and that were developed in the subsequent Green paper will be discussed. In particular the talk will highlight the seamless nature of the climate-weather problem, and the importance of weather phenomena in climate and their resolution in climate models.

Gerald A. Meehl (NCAR)

Next generation climate models for coordinated climate change experiments

What emerged from the IPCC AR4 was a need to transform climate science and transition to a new era of next-generation models to address different types of climate change problems on different timescales with different classes of models. To facilitate this transformation, the international climate modeling community is currently planning coordinated climate change experiments to be run in the 2009-2010 timeframe. Some modeling groups will use higher resolution global coupled models (roughly 50 km) with initialized climate states for decadal prediction (from present to about 2030). Others will use time slice methodologies with global atmospheric models (roughly 20 km resolution), and embedded regional models (some down to 5 km and 1 km) to better resolve midlatitude and tropical storm systems and processes necessary to quantify, for example, regional weather and climate extremes. Newly emerging earth system models with medium resolution (roughly 150 to 200 km) will include, for example, interactive components of carbon cycle, chemistry, aerosols, and dynamic vegetation. This class of model will be used to address longer term climate change (to 2100 and beyond) with new mitigation scenarios. Such climate changes will critically depend on the nature and amplitude of various feedbacks in the coupled earth system, including those involved with the carbon cycle. The climate modeling community will use this new generation of models, that combine advances in resolution and physical processes, to begin to address the biggest challenge in the history of climate modeling: quantify time-evolving regional/local climate changes to which human societies will have to adapt.

Mel Shapiro (UCAR)

The socioeconomic and environmental benefits of a weather, climate and earth-system observations and prediction project for the 21st century

This lecture was prepared in collaboration with scientists from the World Meteorological Organisation (WMO)-World Weather Research Programme (WWRP), World Climate Research Programme (WCRP), International Geosphere-Biosphere Programme (IGBP), and the natural-hazards and socioeconomic communities. It is based upon the paper tabled at the Ministerial and Plenary Sessions of the Group on Observations (GEO) Summit, convened in December 2007, Cape Town, South Africa; *Shapiro*, *et. al.*, 2007. The effort is intended to inform policy makers, national academies of science and users of weather, climate and environmental information of the necessity for establishing a Weather, Climate and Earth-system Observation and Prediction Project to increase the capacity of disaster-risk-reduction managers and environmental policy makers to make decisions to minimize and adapt to the societal, economic and environmental vulnerabilities arising from high-impact weather and climate. This endeavor is as ambitious as the Apollo Moon Project, International Space Station, Genome Project and Hubble Telescope with a socioeconomic and environmental benefits-to-cost ratio that is much higher. It will provide the capacity to enhance the use and benefits of the observations, prediction and early-warning system components of the Global Earth Observation System of Systems (GEOSS). It will accelerate advances in weather, climate and Earth-system prediction and the use of this information by global societies. Delivering the benefits will require building upon the Group on Earth Observations (GEO) and the WMO as international organizational frameworks to coordinate the Project across the weather, climate, Earth-system, natural-hazards and socioeconomic disciplines. The effort will require investments in: i) maintaining existing and developing new observational capabilities; ii) advanced high-performance computing facilities with eventual sustained speeds of >10,000 times that of the most advanced computers of today, linked to a global network of research and operational-forecast centers and early-warning systems; iii) science, technology, and education projects to enhance knowledge, awareness and utilization of weather, climate, environmental and socioeconomic information; iv) infrastructure to transition Project research achievements into operational products and services.

Taroh Matsuno (Frontier Research Center of Global Change, JAMSTEC)

Toward the realization of cloud-cluster resolving AGCM – necessity and feasibility

In the past half century since the first numerical experiment by Phillips (1956) appeared, AGCM has made a great progress and the models are successfully applied to operational NWP and climate change projections. However, the past and current models are basically intended to reproduce middle to high latitude weather/circulation systems such as extratropical cyclones, anticyclones, fronts and so on, which are generated by baroclinic instability. In contrast to this, in the tropics convective motion due to static instability dominates. The convections appear as "mesoscale convective system (MCS)" with definite structure as its elementary form. Occasionally they produce larger-scale phenomena like Madden Julian Oscillation. Despite its importance in the scientific and practical contexts the convections have not been treated explicitly in AGCM because of its small size. By ever increasing computer power now, it becomes possible to simulate general circulation by explicitly treating MCSs equally to extratropical cyclones. Non-hydrostatic Icosahedral Atmosphere Model (NICAM) is the first trial toward this direction. Quick results from NICAM experiments will be briefly reviewed and the necessity of such models will be addressed.

Masaki Satoh (Center for Climate System Research, Univ. of Tokyo/Frontier Research Center for Global Change, JAMSTEC)

Ongoing studies with the global cloud-resolving model, NICAM

Global cloud-resolving simulations with mesh size about a few kilometers over the globe are now available with the Nonhydrostatic ICosahedral Atmospheric Model (NICAM) using a high-performance computer, the Earth Simulator. The highest resolution is the 3.5 km-mesh. The NICAM simulations show realistic behaviors of tropical convective system, such as diurnal cycles, cloud clusters and super cloud clusters, an MJO, and tropical cyclones. Interestingly, characteristics of these convective-systems are also captured by a coarser resolution model, 7 km and 14 km-mesh, though there are some biases. This fact facilitates the global cloud-resolving model studies to conduct ensemble experiments on various conditions or longer integrations for years.

The advantage of the global cloud-resolving model is that the multi-scale structure of convective systems from meso to planetary scale is automatically resolved. In a realistic simulation of an MJO event (*Miura et al.*, 2007), NICAM reproduced inner cloud structure of the MJO-cloud-system. The results revealed roles of meso-scale cloud systems in the propagation of MJO. Tropical cyclones in the western Pacific and the Indian ocean associated with the MJO are also represented well. Following this experiment, another MJO case occurred in the period of MISMO (Mirai Indian Ocean Cruise for the Study of the MJO-convection Onset, Nov. 2006) was successfully simulated. Half a year simulation is also conducted and it shows periodicity of MJO. Since the global cloud-resolving model is real and its usefulness is shown, it is a time to consider its practical use for such as numerical weather forecasts or global warming studies.

John Mitchell (MetOffice)

On resolution, complexity and uncertainty in climate change predictions

As it becomes accepted that human activity is and will continue to affect climate, the emphasis is moving from mitigation to adaptation. This requires detailed predictions of regional climate change and extremes. In order to produce predictions of regional climate, it is essential that the models used produce credible simulations of the main natural modes of variability. It has been argued that very high resolution is required if models are to simulate the non-linear processes which contribute to much of natural variability. If this is so, then it could also be argued that the thermodynamic and biogeochemical processes which are driving climate change need to be simulated to the same degree of accuracy. Until the large uncertainty in some of these processes is reduced, the way forward is probably limited to running large numbers of "physics "ensembles to quantify the range of uncertainty. On top of the requirements for increased resolution, this leads to a huge increase computing capacity.

In this talk, I look at some of the benefits of increased resolution for climate prediction by comparing climate simulations of the MetOffice Unified Model with those made at higher resolution for numerical weather prediction (taking advantage of so called "seamless" prediction). I look at attempts to quantify the main sources of uncertainty in longer-term climate predictions due to subgridscale and biogeochemical processes. I compare the magnitude of local changes due to natural modes of variability with those predicted for increases in greenhouse gases. I conclude with some implications for future supercomputing.

Bjorn Stevens (UCLA)

Why aren't climte models getting better? (But forecast models are.)

The question as to why climate models are not improving is explored in terms of four hypotheses: (i) the premise is false, climate models are getting better; (ii) we do not know what better is; (iii) getting better is difficult (rough fitness landscape, informal model hierarchies), so progress is slow and uncertain; (iv) getting better is impossible (structural instability), because the remaining imprecision of the climate system is irreducible. Although each hypothesis conforms to some degree with our experiences, each is also usefully contrasted with the experiences of the Numerical Weather Prediction community, whose demonstrable progress on a well defined problem is incontrovertible, despite the fact that getting better is difficult even (in a certain sense) impossible. These experiences, it is argued, can help guide the way to improved representations of the climate system, and help motivate some suggestions for future points of emphasis, particularly in light of opportunities for international initiatives.

Isaac Held (GFDL)

Attribution and prediction of regional climate change

The value and limitations of statistical and dynamical downscaling, and high-resolution time-slice simulations with atmosphere-only models will be described briefly, followed by a discussion of some of the challenges climate models face when tackling the problem of regional change, using specific issues (Southwest Australian drought, Sahel drought, Atlantic hurricanes) as examples.

Tim Palmer (ECMWF)

Towards the Probabilistic Earth-System Model

An Earth-System model purports to be a comprehensive algorithm for simulating and predicting variables relevant to the evolution of climate. I would argue that one variable of enormous relevance is "predictive uncertainty". However, most individual Earth-System Models do not have the capability to predict uncertainty. Instead the community estimates predictive uncertainty from the spread of the ensemble of climate models developed around the world. Given the sophistication of both numerical and parametrisation schemes in Earth-System models, it seems unbalanced and hence unsatisfactory to rely on the prediction of uncertainty using such ad hoc and unrigorous multi-model techniques. It is argued here that future Earth-System models should be inherently stochastic. When forecast probability distributions from such Probabilistic Earth System Models become inherently more skilful that those from multi-model ensembles, one of the key reasons for supporting the development of multiple climate models worldwide, will be lost. These issues need to be explored carefully if petascale HPC infrastructure dedicated to climate is funded at the international level.

Walter Zwiefelhofer (ECMWF)

Trends in High-Performance Computing

Over the past few years, chip designers and hardware architects have been working hard to get the escalating electrical power requirements under control. Throughout the microprocessor industry, this is resulting in a massive shift towards multi/many-core processors. This in turn forces the rate at which application developers have to improve the scalability of their codes. There is a debate whether accelerated but incremental code improvements will be sufficient to harness the power of future systems or whether radical changes to the current application codes are unavoidable.

Hybrid systems that combine general-purpose processors with specialised processors are being designed by several vendors. What are the prospects for using specialised hardware for Earth System modelling? The benefits of customised hardware are well documented in several application areas. Is Earth System modelling a good candidate for such specialised solutions or is Earth System modelling better served by general-purpose HPC systems?

Kathy Yelick (UC Berkeley and Lawrence Berkeley National Lab)

Petascale meets multicore: programming model challenges and opportunities

Petascale systems will soon be available to the computational science community at multiple sites. These systems will represent a variety of architectural models, but with one common component, which is an increasing reliance on multicore technology as the building block for these machines. The earliest Petascale machines will have a modest number of cores per chip, but conservative estimates are that these numbers will double every two years. One of the driving forces behind multicore throughout the computing industry is power density, since multiple cores require less power than a single core with equivalent performance. The power issue will be increasingly important if we intend to build Exascale systems, as total system power is one of the major impediments to Exascale. In this talk I will describe some of the challenges that application scientists and algorithm developers will face in utilizing these future high end systems and how growing on-chip parallelism will change the way we think about parallelism and scaling. I will use computational problems within climate modeling to illustrate these issues. This shift towards multicore also brings into question the message-passing programming model that has dominated high-end programming for the past decade. I will also present an alternative to message passing called Partitioned Global Address Space (PGAS) languages and describe some of the performance and scaling advantages. Finally, I will propose a new notion of high end programming in which software is designed up-front to be adaptable to current and future systems.

Omar Ghattas (University Texas)

Towards advanced numerical algorithms for computational science on petascale systems: Dynamic mesh adaptivity, Newton-Krylov inverse solvers, and uncertainty quantification

Hardware advances by themselves are not sufficient to address abiding grand challenge problems in the Earth Sciences. New scalable numerical algorithms are required that overcome the curse of dimensionality related to multiscale processes and uncertainty quantification. Here we discuss new parallel algorithms for dynamic mesh adaptivity, inverse solvers, and Bayesian inference that are capable of scaling to parallel systems with tens of thousands of cores. We cite representative results on several geoscience problems on Ranger, the new 63000 core, 0.5 petaflops system at the Texas Advanced Computing Center.

David Parks (NEC)

The NEC perspective for Earth System Modelling

Abstract not available

Per Nyberg (Cray Inc.)

Towards an optimal architecture for earth system modeling

As early adopters of high performance computing, scientists studying the weather, climate and oceans pushed supercomputers to their limits with the computational demands of numerical modeling. System requirements for sustained performance grew exponentially as the science evolved and numerical models were developed with more accurate representations of physical phenomena. What has remained constant is the need for better simulation accuracy to continue advancing scientific research. The practical impact of weather, climate and ocean prediction on the world population and economy drives investment in and use of high performance computing in the Earth Sciences.

With increasing observational capabilities, modeling complexity and inter-disciplinary collaboration, the Earth Sciences community will continue to be a leading driver in the push towards higher productivity computing and the practical realization of a sustained Petaflop. In areas such as performance, system management and data management, earth system modeling presents unique challenges in HPC. In addition to floating point performance, memory access and inter-processor communication patterns are typically both latency and bandwidth sensitive placing a multi-faceted challenge on computing architectures. The computational requirements for simulations of appropriate spatial and temporal scales demand both capacity and capability computing across a diverse workload and at extreme scale. Maximum scalability of both hardware and software must be addressed in order to efficiently execute these workloads in practical time frames on infrastructures that are continuously increasing in size and complexity.

In recent months the high performance computing (HPC) community has witnessed a number of installations and solicitations for capability systems in the hundreds of teraflops. The realization of Petascale facilities in the coming years will open new areas for research and present new HPC challenges. A close relationship currently exists between the earth system modeling and HPC vendor communities. Each is a key component in advancing the state of the other. Scientific challenges initiate the design of new technologies, computer architectures and HPC facilities, and system acquisitions as a whole fund basic research and development. New HPC technologies allow for the improved modeling of known phenomena and stimulate the discovery of unknown phenomena. As we enter into the Petascale era, a determinant for success will be for the earth system modeling and HPC vendor communities to further foster their relationship through greater levels of cooperation.

Cray is proud to be a partner in a number of leading centres that are pushing the boundaries of system scale and providing leadership computing capabilities to climate researchers. These centres include the Oak Ridge National Laboratory (250+ Teraflops), Sandia National Laboratories (124 Teraflops; upgrade to 284 Teraflops in mid 2008), National Energy Research Scientific Computing Center (100+ Teraflops) and the UK Engineering and Physical Sciences Research Council High End Computing Terascale Resources project (60 Teraflops), and form an essential step to the practical realization of a sustained Petaflop. In addition, the contracted Petaflop system to be delivered by Cray to the U.S. Department of Energy's Oak Ridge National Laboratory will further support advanced climate research.

This talk will cover the challenges and opportunities for the earth system modeling and industry communities in reaching petascale objectives in the coming years.

Kent Winchell (IBM)

PetaScale computing: capacity or capability

Investigating the tradeoffs of capability or capacity based systems for weather and climate simulations.

Discussion of the tradeoffs of traditional system balance with regards to memory, cores, and interconnect ratios.

Christian Jakob (Monash University)

Evaluating parametrizations in large-scale models – An integrated approach

Processes acting on scales smaller than the grid-resolution of a model must be represented by means of parametrization. Perhaps the most prominent examples are the representation of cumulus convection and clouds in large-scale models as they are used in Numerical Weather Prediction, seasonal prediction and climate simulation. Parametrizations have evolved considerably from simple statistical relationships to quite complex conceptual models. In the case of clouds for instance modern parametrizations aim to directly represent the processes involved in cloud formation and dissipation and the associated latent and radiative heating. This has fundamentally changed the task of parametrization development as well as the model evaluation activities surrounding it. It is no longer sufficient to demonstrate the ability of a model to simulate the mean properties of the parametrized variables, e.g., clouds, on a broad scale, but models are required to do so while employing realistic conceptual models of the processes involved. Furthermore, overall model errors need to be traced back to flaws in the conceptual models, which themselves keep increasing in complexity. The issue is further complicated by the desire to apply the same large-scale model across a variety of applications ranging from Numerical Weather Prediction to seasonal and climate forecasts.

This talk will provide an overview over the considerations required to bring together the sometimes divergent goals of improving parametrizations at the process level whilst at the same time improving a model's performance in its overall application. Using the representation of clouds and convection as examples, an iterative strategy that combines activities in many areas of model evaluation is developed and its application is illustrated. Central to the approach are techniques to objectively decompose model errors into regimes and/or phenomena of interest to the application and to focus parametrization evaluation and development on those regimes that are most likely to impact the model's overall performance in its application. It will be shown that successful model development requires the strong interaction of the modeling and data communities as well as the application of an iterative strategy. Gaps in both the science and implementation of this strategy will be highlighted.

Detlef Stammer (IfM-HH)

Initialization procedures for climate prediction models

In the past climate prediction models were initialized in the 19th century and run forward to simulate present day and future climate scenarios. This initialization procedure introduces a significant uncertainty in simulating future climate change scenarios due to serious uncertainties in their representation of the present day climate state as the starting point for climate scenario runs. In order to remedy this situation, more sophisticated initialization procedures have to be invoked which build on present day climate observations. The talk will focus on challenges of the initialization of next generation coupled climate models through climate data sets and on the potential of improving the skill of those models through assimilation procedures.

Kazutoshi Onogi (JMA)

Evolution of long-term reanalysis

Long term global atmospheric reanalysis was firstly proposed by Trenberth and Olson (1988) and Bengtsson and Shukla (1988). Reanalysis of atmospheric observations using a constant state-of-the-art assimilation model has helped enormously in making the historical record more homogeneous with high quality and useful for many climate studies. Following the proposals, major numerical prediction centers carried out reanalysis projects such as NCEP/NCAR R1, NCEP/DOE R2, ERA-15, ERA-40 and JRA-25.

The third WCRP International Conference on Reanalysis (hereafter 3RAC) was held in Tokyo from 28 January to 1 February 2008. 260 participants from 21 countries of different research areas were coming together. We confirmed that reanalysis has proved to be as valuable for monitoring climate, climate research and applications as it was expected. The conference was dominated by atmospheric scientists but experts on ocean, land surface and polar region largely contributed to discussions from view of interaction with atmosphere. Through the discussion of 3RAC, we recognized benefits from reanalysis and deficiencies of reanalysis to be overcome to produce a more consistent climate datasets.

Kevin E Trenberth (NCAR)

Exploiting and evaluating models with observations

To evaluate and improve models they must be confronted with observations of various sorts and in many ways. This includes performance in short term and seasonal forecasts, the annual cycle, 20th century runs, reanalysis, and paleoclimate simulations. Important metrics include the climate sensitivity and transient climate response which can be assessed somewhat using the annual cycle. Models are useful tools for analyzing and assimilating observations in a consistent physical framework, and such analyses are an essential first step for predictions on multiple time scales. Models can be used to interpret observed historical changes in the climate system. Moreover, reanalysis of past observations provides useful datasets for testing models in hindcast mode, and for improving models through diagnostic studies. New tools are becoming available to allow models to be used in reanalysis mode. Comprehensive budgets of mass, moisture, heat and energy can be used to help evaluate models by comparing deduced fields with those from model parameterized physics and with observations (in some cases, such as precipitation and Earth radiation). Forward models are needed for comparing model generated proxies, such as isotopes and tree rings, with observations, especially on paleoclimate timescales. Models enable assessment of what has happened and why, and should also be used to attribute how the current state evolved to where it is through numerical experiments, and to help assess the state of the climate system and thus confidence in predictions. Numerical experimentation further enables statements about the role of forcings in the observed state. This talk will provide illustrations and emphasize that models form a core tool for a much needed climate information system.

Ari Patrinos (Synthetic Genomics, Inc.)

The GENOME experience

Abstract not available

Julia Slingo (National Centre for Atmospheric Science (NCAS), University of Reading)

Where do we go from here? Possible ways forward for achieving a revolution in climate prediction.

The talk will take as its premise that an enhancement of human and computing resources is essential to deliver the step change in our capability to produce climate predictions, especially at the regional and local level, and with the level of confidence required by society in order for decisions to be taken on how to mitigate and adapt to climate variability and change. It will consider the challenges that face us and the potential options to achieve this change; and it will present some ideas on organisational structures that might serve to deliver this revolution in climate research and prediction in the coming decade and beyond.