Possible questions to consider during Breakout Group discussions

Theme 1:

Background

The WCRP Strategic Framework for 2005-15 "Coordinated Observation and prediction of the Earth System" and the Green paper "A Revolution in Climate and Weather Prediction - Towards a Seamless Process for the Prediction of Weather and Climate", discussed at the 2007 WCRP JSC meeting, provide the background for the discussion. The argument was made that the revolution was both possible and necessary. In the discussion of this, the notion of a seamless climate-weather problem was introduced.

Questions

- What are the crucial questions being asked of our community by society?
- Is a "revolution" both possible and necessary?
- To what extent is the notion of a seamless climate-weather problem valid and useful?
- What should be the approach to solving the problem?
- What can we promise to those who fund the venture?

Theme 2:

Questions

- What and how strong is the evidence for 'serious limitations' in current climate models?
- If there are serious limitations in simulating the physical climate system, should we be directing much more resources towards alleviating them e.g. better parametrizations or higher resolution rather than massively increasing the complexity of the earth system simulation?
- Is the low resolution currently used due only to lack of computer and human resources or lack of understanding and 'cultural inertia'?
- Does the experience of NWP and early efforts with very high resolution climate simulations confirm that much higher resolution is essential?
- If the answer to the question above is yes then why are we not doing more?
- How strong is the evidence that resolving deep convection in large-scale models gives improvements to the forecasts and simulations, and hence provide fundamentally change the efficacy of climate prediction and projection?
- Is it possible that climate models will respond more nonlinearly to imposed climate forcing's in models which resolve deep convection, compared with the current generation of climate models?
- Do stochastic techniques provide an alternative to ultra-high resolution?
- Do RCMs necessarily improve the reliability of regional climate change forecasts? Is there a need for RCMs when deep convection is resolved in global climate models?

Theme 3:

Topics

- Prospects for high-end computing hardware in the next decade
    - Conventional systems anticipated from commercial vendors
    - Potential for hardware customization for climate simulation
- Prospects for petascale software
    - System-level software (compilers, etc.)
    - Frameworks
- Prospects for evolving climate model design
    - Innovative numerical methods (adaptive mesh refinement, grids without singularities, etc.)
    - Dynamic load balancing

Questions

- STRATEGY. What is the best strategy to provide sufficient computational capability to enable the development and operation of dramatically higher resolution and higher complexity weather, climate- and Earth-system models in the next 10 years? In particular, should partnerships between the modelling community and the chip/system design community be fostered toward the development of a specialized "climate computer"?
- HARDWARE. What are the current status and current trends in high-end computing? What are the requirements for weather and climate modelling for the next decade? Are current plans by the commercial high-end computing vendors likely to produce systems capable of addressing those needs?
- SOFTWARE. What are the current status and current trends in petascale software? How can the weather and climate models take advantage of these developments? Are sufficient resources being dedicated to the development of software environments to support weather and climate modelling?
- MODELS. What are the current status and current trends in global weather and climate model design? What advances in fluid dynamics modelling in other fields have been made or are anticipated and have the weather and climate model development groups taken advantage of these developments?

Theme 4:

Topics

- Process-based model evaluation
- Data assimilation (DA), analysis, and initialization of climate prediction models
- Metrics for quantitative model-data comparisons
- Detection and attribution of major climate signals
- Parameter sensitivity: Large ensembles and emulators
- Structural uncertainty: MIP's

Questions

- Can we define a strategy for model evaluation that spans a hierarchy of scales and processes? Can we identify key uncertainties for which this process-based evaluation is essential, and other key uncertainties for which it is less important? Such a separation might be important to keep the evaluation process manageable. How do processes integrate into an overall model sensitivity?
- Can climate models or their components be initialized and used for "reanalysis" of observations and does this improve evaluations and insights for model improvements? What progress is required before we can initialize coupled climate prediction models? Is it sufficient to perform uncoupled initializations and then couple the initialized component models? We know several candidates that have the potential for carrying decadal climate predictability – the ocean, sea ice, soil moisture, and the stratosphere. How can we find out most effectively which of these candidates indeed leads to better predictions?
- Can we define a manageable set of metrics that allow us to quantify how well models fit observational data? What metrics map onto climate sensitivity? Can we map any metric onto a purpose for which it is defined? Do we have to take special measures to avoid that the means is turned into an end, that is, to avoid that the metrics themselves, rather than model improvement, become the target?
- Do climate models correctly simulate major climate signals such as the retreat of Arctic summer sea ice during 2007? How much of the discrepancy is due to inherent predictability issues versus model deficiencies? How much is attributable to "external" forcing versus "internal" evolution? In the latter case, how critical are the initial conditions? If an atmospheric model can simulate an event with observed sea surface temperatures, why were the SSTs the way they were? Are there climate signals that models cannot be expected to simulate correctly even under the best circumstances? Can we attribute major climate signals to specific causes, thus explaining how they arose? What does ability to simulate immediate past events (or otherwise) map onto confidence in future predictions?
- Do we have an adequate strategy to investigate parameter sensitivity in models? Do we have the appropriate statistical framework? Do we know how to sample parameter space, both conceptually and efficiently enough? How does parameter sensitivity map onto model sensitivity?
- Given the large number of MIP's that have occurred so far, do we have an adequate MIP strategy? Is that MIP strategy comprehensive enough to give us insight both into how realistically or unrealistically models simulate the world, and insight into knowledge about how models differ from each other, thus pointing at key structural uncertainty? Is it time to stop treating all models as equals in the IPCC multi-model ensemble? How do MIP's lead to model improvement?

Theme 5:

Background

This Theme will take the statement of requirements produced by Themes 2, 3 and 4 and consider the potential options to deliver them. It will also consider how best to demonstrate the substantial socio-economic benefits of more confident and skillful predictions of climate on all timescales. Arguably this has yet to be achieved, but will be crucial in convincing governments and funding bodies to provide the level of resource that is required. It cannot be assumed that these benefits are self-evident.

The outcome of the Theme will be a proposal or set of proposals to pursue a particular course of action for which a mandate will be sought from the Summit to take forward at the highest level.

The Theme will take as its premise that **an enhancement of human and computing resources is essential** to deliver a step change in the capability to produce climate predictions with a significant increase in confidence at the regional and local level accompanied by reliable estimates of uncertainty.

The purpose of the discussions is to consider the options for achieving this enhancement through, **national, international and/or global actions**. They should consider both the hardware infrastructure requirements to deliver the computational power as well as potential organizational frameworks that might facilitate greater intellectual firepower. The emphasis should be on visionary solutions rather than 'business as usual', but respecting the current status of national developments and needs.

Questions

- What is the strategy to ensure enhanced and sustained modelling efforts and computing power at the existing modelling centers of the world? Or, is the scale of the challenge so large that in addition to the current national efforts, a far more comprehensive, and internationally coordinated approach is needed?
- How can we convince governments and funding agencies of the immense economic value of an increased capability to produce information on regional and local changes and variations in climate, which are of sufficient accuracy to enable well-informed decisions on adaptation and mitigation options to be taken? Do we need a demonstration project and if so what form should it take? How or should such a project influence the structure and remit of the next IPCC assessment?
- What are the best strategies to foster collaboration and interaction among the weather/climate modelling community, computational fluid dynamics community and computer (and chip) manufacturers to achieve a million fold increase in the *effective* computing power for climate and weather modelling and prediction (NB more efficient codes will be part of this delivery mechanism)?
- What are the best strategies for fostering collaborations among existing centers around the world to tackle the *intellectual* challenge of achieving this step change in climate modelling and prediction? What role should the WCRP play in facilitating this?
- Has the time come for the climate modelling community of the world to establish a dedicated supercomputing facility and a collaborative research framework for climate and weather modelling and prediction that is beyond the capability of a single nation?