WCRP
World Climate Research Programme

WCRP Community-wide Consultation on Model Evaluation and Improvement

Please complete the following template by writing your answers into the boxes below the questions, sending any supplementary material such as clearly labeled figures in a separate file. Please submit your response electronically by ***15 September 2009*** to Anna Pirani at apirani@princeton.edu.

Q1: Please state your particular area of interest, e.g. global or regional climate or NWP modeling, seasonal prediction, sea-ice feedbacks, monsoons, troposphere-stratosphere exchanges, etc.
NWP and environmental applications, e.g. chemical weather forecast (CWF)

Q2: Given your interest, what would you consider/identify as the KEY uncertainties/deficiencies/problems of current models? What do you think should be evaluated/improved as a priority in models in terms of parameterization and/or interactions among processes? (Give references and/or one key figure where possible)
Key discrepancies between our current understanding of PBL processes and parameterisations in operational NWP models is noticeable. Operational NWP, climate, emergency response, and air quality models that are run on everyday schedules usually employ first or 1.5 order turbulence closures and are of RANS type. More sophisticated turbulence descriptions, as in LES models, are used for research applications, but are too time consuming for current operational applications.
The trend to still higher spatial resolution (approaching up to 1 km in NWP modelling) leads to several problems with respect to PBL descriptions: (i) parameterizations could be inadequate since they were developed for coarser hydrostatic numerical models over essentially flat and horizontal terrain; (ii) available surface information is not as detailed as needed, due to lumped-parameter descriptions; (iii) near-surface exchange schemes are not appropriate for rough surfaces ; (iv) high spatial resolution in complex terrain leads to steeper slopes and thus problems with respect to non-hydrostatic effects, radiation (e.g., shading), numerics (e.g., instabilities), adequacy of parameterizations in general, and local meso-scale flows, not properly resolved, but perhaps dominant in local energetics or mass budgets.
Areas of necessary improvement include turbulence closure, meso-scale convection and overall treatment of complex terrain and rough surfaces. It is thus important not to just fix existing schemes, but to develop new ones based on sound physics and numerics. The success of PBL descriptions in operational models will, to a large degree, be dependent on improved assimilation techniques for PBL data that account for not only statistical, but physical, flow properties. Other sub-grid scale issues (e.g., flux aggregation, cloud-radiation interaction) are also important.
Potential for 'double-counting' of TKE in RANS models exists. If the model resolution drops below a certain threshold, the largest turbulence scales become explicitly resolved while still implicitly covering the entire spectrum in its turbulence parameterization.
The background Monin-Obukhov similarity theory is not applicable over complex terrain and does not realistically reproduce strongly stable and strongly unstable stratification regimes. Recently it has been generalised accounting for the non-local effects of the free-flow stability in stable stratification and large-scale, organised eddies in shear-free convection. Further work is needed to extend the surface-layer theory to sheared convection and also to complex and sloping terrain.
The parameterizations of clouds and precepitation have a number of problems to be overcome in NWP models. First, there exists a variety of cloud types, they are formed, maintained and dissipated by different physical processes, such as convection, small-scale turbulence, large-scale ascent or descent, and cloud microphysical processes that lead to the generation of precipitation. Many of these processes are poorly understood and act on scales smaller than those resolved in mesoscale model, which makes them the subject of physical parameterization themselves. Furthermore, the radiative effects of clouds depend on a large number of different cloud (as well as aerosol) parameters that all need to be described accurately to

ensure their correct treatment in the radiation parameterization.
Another area of needed research is the nesting of micro-scale and mesoscale models. The simplest method is one-way downward nesting, in which the meso-met model provides 4-D boundary conditions to the micro-met model. In the more advanced two-way nesting, the micro-scale model also provides lower boundary condition fluxes to the meso-met model. With current computer capacities, this can only be done within a small part of the mesoscale domain, which creates consistency problems with the remaining parts of that domain.
Main topics expected to improve the reliability of chemical weather forecasts include: (i) emission uncertainties, (ii) integration with meteorological drivers, (iii) evaluating the boundary conditions, (iv) assimilating measured data into the models, (v) improved understanding of physical processes (especially within PBL), (vi) evaluation of models against data, (vii) generation of model ensembles.
The on-line integration of NWP or other meteorological models, with atmospheric aerosol and chemical transport models (CTMs) gives a possibility to utilise all meteorological three-dimensional (3D) fields in CTM's at each time step, and to consider feedbacks of air pollution (e.g., those due to urban aerosols) on meteorological processes and climate forcing, and further on the chemical composition. This is one future direction of research (as a part of and a step to Earth Modelling Systems), and could lead to a new generation of models for NWP and CWF.

Q3: Do you see a particular gap (in knowledge, in observations or in practice) that would need to be filled, or a particular connection between different modeling communities or between modeling, process studies and observations that should be made a priority?
NWP modelling community and Remote Sensing /satellite monitoring community have to work much more closely. Data assimilation of different type of such monitoring data is one of the most important issues.

For evaluations of online integrated NWP-ACT models it is not enough to validate separately the meteorological model (with switched off ACTM) and ACTM driven by meteorological fields from NWP model without including aerosols and other precursors feedbacks. If we consider the feedback mechanisms into integrated models we also have to validate additionally both parts including the feedbacks in both directions. Currently the COST Action 728 'Meso-meteorology for atmospheric pollution modelling' (http://www.cost728.org) makes an inventory of validation approaches and will build recommendations for the integrated model quality assurance procedure.

Increased resolution in NWP models allows for more realistically reproduced urban air flows and air pollution processes, which has triggered new interest in modelling and investigating experimentally specific processes in urban areas. A deeper understanding of urban PBL dynamics requires development of long-term urban test beds in a variety of geographic regions (e.g., inland, coastal, complex terrain), in many climate regimes, and with a variety of urban core types (e.g., deep vs. shallow, homogeneous vs. heterogeneous). Ideal urban test beds would include quasi-permanent mesoscale networks, with surface, canyon, rooftop, and PBL meteorological and air quality observations, as well as intensive short-term field observational studies that could involve turbulent flux and pollutant tracer measurements.

Ensemble modelling - more theoretically grounded methodology for building of the model ensembles is needed.

Q4: Do you see any particular resource or opportunity within the modeling/process study/observational/theoretical community (e.g. new results, new observations) that would be particularly useful and should be exploited to tackle this problem?
For complex and related meso-scale PBL flows in NWP, climate and environmental models, a unifying theory is still missing.
Creation of a catalogue of data from complex PBL field studies would be extremely useful.
See also in Q3.

Q5 What would best accelerate progress on the topics raised in questions 1-4? Do you have suggestions for new initiatives (new process studies, field campaigns, or new collaborative approaches, eg international Working Groups, Climate Process Teams)?

It would be important to initiate an international Working Group on Integrated NWP-ACT modelling (first step was done by the COST728 e.g. on the Copenhagen workshop, see http://netfam.fmi.fi/Integ07/index.html)

Q6: Any other suggestions/issues to be raised?