WG1: Representing initial and model uncertainties

The Working Group (WG) on representing initial condition and model uncertainty met at ECMWF on November 8-9, 2007. There were 23 participants, and Roberto Buizza and Ben Kirtman co-chaired the WG. The following summarizes the WG discussions and concludes with some ECMWF specific recommendations that are motivated by the consensus opinion that emerged from the deliberations.

The WG deliberations began with a detailed discussion of a series of questions:

1. What is the main contributor to forecast uncertainty? Initial condition uncertainty or model uncertainty?

The WG discussed whether initial condition uncertainty can be separated from model uncertainty. It was immediately recognized that model uncertainty makes significant contribution to initial condition uncertainty. Nevertheless, it is possible to diagnose the contribution to forecast error associated with model error by assuming a perfect model approach initializing forecasts using the Ensemble Kalman Filter (EnKF), and to a lesser degree using the ensemble 4-dimensions variational approach.

The WG had extensive discussions regarding the fact the model error and uncertainty needs to be diagnosed at the process level. Indeed, the WG felt that it was important to distinguish between model error associated with limitation in horizontal and vertical resolution versus errors in the parameterization of the physical processes. The WG also was careful to acknowledge that resolution and parameterization are closely linked.

The WG acknowledged the fact that there is still no agreement on whether one of techniques used to simulate initial uncertainty is superior to the others, and recognized the value of studies designed to compare ensembles based on different methodologies. But overall, the WG concluded that given the current status of ensemble prediction systems, research priority should be given to improving the simulation of model uncertainty and reducing model errors/biases.

2. Are ensemble prediction systems sampling initial condition uncertainty properly?

The WG consensus is that there is a need to improve the sampling of initial condition uncertainty. The WG discussed the fact that current techniques (e.g. singular vectors and bred vectors) for sampling initial condition uncertainty selectively probe that uncertainty (i.e., they capture the fastest growing perturbations), and that there is still no agreement on whether such a 'selective sampling' approach is needed. The WG pointed out that there are serious data and modeling issues associated with sampling land surface initial condition uncertainty, which have received relatively little attention.

3. Are ensemble prediction systems sampling model uncertainty sufficiently?

The WG agreed that there is much work to be done in terms of improving the simulation of model uncertainty and in terms of reducing model biases. The WG recognized the current approaches to simulating model uncertainty, e.g., schemes based on stochastic perturbations added to model tendencies due to physical parameterization (i.e. the schemes operational at ECMWF and MSC) and schemes based on stochastic backscatter ideas (e.g. the ones under development at the UK Met Office, ECMWF and MSC), but also acknowledged that these approaches have limitations. The WG agreed that future efforts in simulating model errors should have linkages to the physical process and parameterizations. There was also some discussion

regarding the simulation of know model errors on the largest scales with particular emphasis on the MJO. In terms of model biases/error, the WG discussed the possibility of examining the parameterization problem by including space-time coherence.

The discussion of question 3) closed with a clear consensus that the multi-model approach to ensemble prediction is an extremely pragmatic and useful mechanism for sampling model uncertainty, but it should not be used to avoid the difficult problems of improving model of model uncertainty or reducing model errors and biases.

4. How do model-component interactions (i.e., atmosphere-ocean, atmosphere-land …) contribute to model uncertainty?

The WG concluded that there are large errors in the individual component models and in their interactions that require further documentation and understanding, and that the addition of the simulation of these interactions may increase substantially the forecast skill in some regions (e.g. the inclusion of sea ice-atmosphere interactions might improve the forecasts of temperature evolution close to the polar caps). The WG also discussed additional issues regarding the additional model complexity (i.e., biogeochemical cycles). While the WG felt that these processes might prove to be important for ensemble prediction systems, some caution was expressed. Specifically, there is the concern that these model-component interactions might add noisiness to the system that is not well understood.

The WG also discussed the utility of making weather forecasts with coupled models and agreed in principle that this is desirable.

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5. Resolution versus ensemble size?

The WG spent some time discussing the trade off between ensemble size and ensemble member resolution. In general, the WG felt that this issue needs to be revisited with the goal of potentially increasing the resolution of the ensemble members.

The WG also thought that the relative value of a single higher-resolution forecasts versus an ensemble of lower-resolution forecasts should be re-assessed with state-of-the-art systems (no conclusions on this issue were drawn).

The WG acknowledged the value of variable resolution approaches to ensemble prediction, but pointed out that “shock” issues associated with truncating the resolution of ensemble members (e.g. from TL399 to TL255 at day-10 in the ECMWF VAREPS) need to be documented in more details.

The WG agreed on the following list of specific recommendations to ECMWF:

- More Emphasis should be given to understanding model error, and to improving the simulation of model errors on weather and seasonal time scales. Developments along this lines would benefit from a very close interaction between scientists developing paramtrization schemes and scientists developing “models of model errors”
- The impact of using of coupled models in weather forecasting systems (high-resolution, ensemble) from initial time should be documented, and if beneficial should lead to coupling from step zero

- Different ensemble configurations, e.g. with a smaller ensemble size but a higher resolution, should be investigated, taking into consideration the fact that:
    - The answer might be user/application dependent (users should be involved/consulted)
    - If a variable resolution is used, the shock due to the resolution truncation should be studied and properly documented
- The impact on the ensemble performance of raising the top of the model and of increasing the model resolution in the stratosphere should be investigated
- The TIGGE data-based is an extremely valuable data-set: ECMWF should consider to extend it to seasonal time scales
- Experiments should be designed and performed to diagnose and isolate model error (e.g. using ensemble 4-D Var) specifically by assuming there is no model error in the data assimilation system and then forecast error is due to model error.
- Work on ensemble 4-D Var data assimilation should continue:
    - 4-D Var ensemble methods should be compared with EnKF methods
    - The investigation on the use of an ensemble of perturbed 4-D Var analyses in ensemble prediction should continue
    - Collaboration with other Operational Centers on EnKF Data Assimilation should be promoted