## Guidelines on Using Information from EPS in Combination with Single Higher Resolution NWP Forecasts

## (CBS Expert Team on EPS, February 2006)

### Motivation

Traditionally forecasters have focused their attention on finding the most likely solution for the future weather. This is the first and most important aspect of weather forecasting. As the lead time for forecasts increases, the uncertainty associated with the most likely solution generally also increases. Information about the uncertainty in the forecasts is critical for a large group of users. One way of assessing uncertainty in traditional single (or "control") forecasts is through collecting verification statistics over a period of time, and using the error statistics as a way of providing a distribution of expected errors in a forecast. This process, however, assumes that errors for a given lead time are stationary. Operational experience shows that this is not a valid assumption. NWP-based ensemble forecast systems were designed, through dynamical methods, to quantify forecast uncertainty as a function of uncertainty in the initial conditions, in the NWP model, and the evolution of the atmosphere under different synoptic situations. The ET-EPS recommends the more widespread use of EPS systems to provide the best estimates of forecast uncertainty.

Properly describing the uncertainty in any forecast requires the use of probability distribution functions (pdfs). An EPS can be used to form such a pdf in a consistent manner. Due to resource limitations, EPS systems involve many forecast integrations and therefore often have to be run at a somewhat reduced resolution. Questions arise as to the compatibility of information from a single higher resolution integration versus an ensemble of lower resolution runs. In particular, higher resolution integrations generally show a lower level of systematic error, and may simulate certain aspects or phenomena of the atmosphere with more fidelity (e.g., diurnal cycle, meso-scale features, frontal structures, etc.). Guidance has been sought by WMO members as to the proper use of high-resolution control and lower resolution ensemble information, in particular regarding when information from one or the other system may be more relevant and how they can be best combined/utilized in the forecast process.

### Determining the most likely scenario

The initially symmetric cloud of possible solutions that are centered around the control analysis in a set of ensemble forecasts deforms with time into an irregularly shaped cloud. This is due to nonlinear processes that necessarily displace the control from the center of the cloud. The critical level of nonlinearity is reached sooner for smaller scale and/or more unstable phenomena. For example, in case of convective precipitation, linearity may be lost in a matter of hours, while large scale features may retain linearity for several days.

A forecaster can assess how much weight to place on a single high-resolution forecast (or on the ensemble control) from the spread in the ensemble. Small spread in the ensemble provides confidence in the single forecast, while larger spread indicates that it is essential to include information on forecast uncertainty. If the single model forecast is significantly different from the ensemble mean, in relation to the spread, then very little weight should be given to the high-resolution forecast.

As spread increases, it is less appropriate to rely on a single forecast as the most likely scenario (be it the high resolution or the control forecast of the ensemble). All solutions in the ensemble must then be considered when weighing the likelihood of different forecast scenarios . However, until the lead time where an ensemble indicates large forecast uncertainty, a high resolution control forecast can be utilized in the formation of the most likely scenario. Once nonlinearities become dominant, the high resolution control forecast should be considered only to analyze detailed structure of relevant phenomena indicated, but not necessarily resolved well by the lower resolution ensemble members. However, one should keep in mind that the higher resolution control has its own limitations (e.g. biases in two model resolutions may not be drastically different etc). In less predictable situations the most likely scenario can be derived from the ensemble, e.g., the ensemble mean, median or mode.

**Assessing forecast uncertainty**

So far we have focused on the estimate of the most likely state of the system (first moment). Regarding the important issue of assessing the uncertainty in the most likely forecast (second and higher moments of the pdf), the lower resolution ensemble can be used. As long as the best estimate of the state is based on the ensemble solutions (including the equivalent resolution control that we consider as a member of the ensemble), the same solutions offer a proper way of quantifying forecast uncertainty. For example one can consider the 10, 50, and 90 percentile values in the ensemble distribution at any point and lead time as a simple measure of predictability. If necessary, additional percentile levels can be added, or a detailed pdf can be provided. If the forecaster's best estimate of the state is based more on the high resolution control forecast, the range of ensemble solutions, with a good approximation, can still be considered for establishing a range of possible solutions as far as the scales resolved by the lower resolution ensemble are considered. Consider a thought experiment where an ensemble with the higher resolution model is run (that we cannot afford in real practice due to computer limitations). We expect that uncertainty regarding the larger scales resolved by the higher resolution ensemble would be very similar to that captured by the lower resolution ensemble. What will be missing from the uncertainty estimate derived from the lower resolution ensemble is related to the smaller scale details that are represented only by the higher resolution model.

These guidelines were written as a first attempt to reconcile the concepts of using single high resolution forecasts and EPS in the weather forecasting process. Many more tools than those described above are available at advanced centres including probabilistic forecasts, assessment of alternative scenarios (clusters, tubes, and other classification techniques). Based on such a rich array of ensemble-based tools, the ET-EPS recommends more widespread use of EPS in weather forecasting.

**Developments on post-processing**

The aim of post-processing should be to produce a pdf taking account of information from both single high-resolution model run and EPS members. In general it is expected that in short-range forecasts high weight will be attached to the high-resolution forecasts and lower weights to the perturbed members whereas for the longer range forecasts it is expected that similar weights will be applied to all members. Post-processing methods to achieve this are under development.

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