The Origin and Modeling of Uncertainty in Numerical Weather Prediction

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Abstract

For many aspects of numerical weather prediction it is important to have good error statistics. Here one can think of applications such as data assimilation, model improvement and forecasting.

The data-assimilation procedure updates an estimate of the state of the atmosphere with new observations. The current estimate of the atmospheric state has itself been obtained from a short integration with a numerical prediction model of an estimate valid at an earlier time. It is described using of order 10 000 000 coordinates. Every six hours we have of order 100 000 observations of different aspects of the state of the atmosphere. To combine the vector of observations and the state vector we need an estimate of the error covariances of both vectors.

The high dimensionality of the estimation problem, and the significant cost of operations with the prediction model, suggests that Monte-Carlo methods be used to obtain error statistics. This leads to an ensemble of about 100 states that can be used to describe the uncertainty in the short integration that is required by the data-assimilation procedure. A longer integration of the same ensemble can provide the error statistics for the forecast that is issued to the public.

In the Monte-Carlo procedure, one has to sample both the uncertainty in the observations and the weaknesses of the forecast model. If the weaknesses of the model were limited to a few parameter values that are known only with limited precision, these parameter values could themselves be obtained from the data assimilation procedure. However, the forecast model consists typically of 100 000 lines of code and its behavior differs from the atmosphere in ways that are currently only partially understood. This makes it particularly difficult to describe (and sample) the weaknesses of the model.

The approach used to deal with these various issues in the Canadian ensemble prediction system will be presented.