Making use of the information in ensemble weather forecasts: comparing the end to end and full statistical modelling approaches

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Abstract

We discuss how ensemble weather forecasts can be used, and highlight the advantages and disadvantages of two particular methods.

1 Introduction

Traditionally weather forecasts have been generated from single integrations of weather simulation models. Recently, however, ensemble integrations have also been used to generate weather forecasts. Ensemble integrations are created from the same weather simulation models as are run for the single integrations but run in parallel in a number of different configurations. Each configuration gives a slightly different forecast. From the point of view of forecasting temperature, the main reason for the ensemble approach to weather forecasting is that the average of the forecasts from the different models is a better prediction than the forecasts from the individual models themselves.

There are also other possible benefits from ensemble forecasts such as:

1. that the spread across the ensemble could be used to give a useful indication of the uncertainty in the forecast
2. that the ensemble spread could be used to predict the width of the distribution of future forecast changes
3. that the temporal correlations in the ensemble could be used to predict temporal correlations
4. that the spatial correlations in the ensemble could be used to predict spatial correlations

Given all this potential information, how should such ensemble weather forecasts be used by entities who wish to predict the distribution of some variable that depends on the weather? We will discuss the pros and cons of two methods: the first is the end to end approach (Palmer (2002)), and the second we will call the full statistical modelling approach.

2 End to end use of ensemble forecasts

2.1 Uncalibrated end to end use of ensemble forecasts

Uncalibrated end to end use of ensemble forecasts works as follows. Each ensemble member from an ensemble forecast is converted directly into a variable of user interest. This gives a number of values for the user variable, and these are then interpreted as samples from an estimate of the future distribution of this variable.

This approach is not accurate, as is well known, because the weather simulations in the ensemble need extensive calibration before they can be considered as good estimates of the future weather. This leads to the following method.

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1This is often assumed to be true, although as appropriately sceptical empiricists we observe that this has never been proven. In other words forecasts derived using the spread and past forecast error statistics have never been shown to be better than forecasts derived using past forecast error statistics alone. Our own research (Jewson (2003b) and Jewson et al. (2003)) has so far failed to show any material benefit of using the spread as a predictor in either weather or seasonal forecasts.
2.2 Calibrated end to end use of ensemble forecasts

The problem of lack of calibration in the ensemble members can be partly overcome. If we consider temperature, which is reasonably close to normally distributed, then the mean and the standard deviation of the ensemble can be adjusted rather easily (using calibration methods such as those described in [Jewson (2004)]) while still preserving the individual ensemble members. The calibrated ensemble members can then be converted into the variable of user interest. This method would be appropriate in some cases. However, it has two limitations. These are discussed below.

2.2.1 The correlation problem

For some users of weather forecasts the temporal correlation structure of the weather is important (in addition to the marginal distribution of weather at a fixed time). As an example, consider a business that cares about the distribution of possible amounts of money that it will lose due to the weather over the next ten days, and imagine that it is the number of freezing days that drives loss. The autocorrelation in weather variability needs to be predicted correctly for the distribution of loss to be predicted. Weather that is highly correlated in time is more likely to lead to a run of freezing days and hence a very high loss. Correlation is not perfectly forecasted by numerical weather prediction models, and, like all other aspects of forecasts, needs calibration ([Jewson (2003a)]). The catch is that it is very difficult, if not impossible, to perform correlation calibration and still preserve the ensemble members. Thus if one restricts oneself to the end to end use of ensembles one can never avail oneself of an optimum forecast of the correlation.

2.2.2 The ensemble size problem

For some users of weather forecasts the extreme tails of the distribution of future weather are important. By definition, these are not well sampled by ensemble forecasts with only a small number of members. For instance, consider a business that goes bankrupt if it freezes during the next 10 days, but that freezing has a probability of 1 in 100. End to end use of ensembles for ensemble sizes that are not much greater than 100 will not estimate the probability of bankruptcy very well.

3 Full statistical modelling of ensemble forecasts

The limitations of end to end use of ensembles can be overcome using what we will call the ‘full statistical modelling method’. This method works by ‘deconstructing’ the ensemble completely into a probability distribution (or probabilistic forecast). The original members are lost, and all that remains is the estimated distribution of future weather. This distribution is estimated as an optimal combination of information from the ensemble and from past forecast errors using methods such as those that we describe in [Jewson (2004)]. The advantages of this method are a) the entire distribution of future temperatures can be predicted in an optimal way, making use of all available information including correlation information from past forecast error statistics and b) the ensemble size can be increased as large as is needed (by resampling the forecast distribution) and can hence capture low probability events.

4 Summary

We have discussed the end to end and full statistical modelling methods for making use of the information present in weather forecast ensembles. We find that the end to end method has two shortcomings: sub-optimal correlation forecasts and limited ensemble size. These are both overcome by using the full statistical modelling method.

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