Predicting Indian Summer Monsoon Rainfall: Moving from Multiple to Single Forecast

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The primary source of water in the country is the summer monsoon rainfall in the months of June to September, as more than 80 per cent of the annual total rainfall is received during this season. In India where majority of the population relies heavily on rains for drinking water, agriculture and raising livestock, accurate prediction of summer monsoon rainfall is extremely important. Predicting monsoon rainfall has a long history and dates back to 1886. Since then monsoon forecasting has come a long way from simply observing the sky and earth. With the increased data from satellite observations, improved understanding of the processes, and enhanced computing resources, science pertaining to monsoon has progressed significantly. However, reliability of rainfall forecast is still not adequate, because of its large variability in space and time and its dependence on India's diverse geography, which makes its prediction least accurate compared to other weather parameters and is quite challenging till date.

Over a century, physical laws governing aspects of the atmosphere have been expressed and refined through mathematical equations. The art of predicting weather using numerical techniques by taking advantage of today's modern computational resources is known as Numerical Weather Prediction (NWP) modeling. Simply put numerical model is a representation of a real world system through mathematical equations that can be analyzed using computational methods. These models

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come in handy when analytical solutions and experimental verifications to any such problems are not possible. Over time, NWP models have acquired greater skill and are playing an increasingly vital role in weather forecasting. In the last few decades, great progress has been made by the increasing number of NWP model forecasts.

But, these seemingly big numbers lead to confusion for the general public and for the people who are trying to monitor the monsoon. This calls for the need to develop an effective method to generate a single unified and more skillful forecast compared to the individual ones, on which a user can rely on for making decisions. In view of this, a new approach, known as multi-model ensemble (MME) has gained strong interest in the scientific community in the recent years. Consider figure 1, assume each person to be a model, and everyone to have some information about the unknown distribution. Now if all the information is combined, the unknown distribution can be identified with ease. Analogically, different models have different strengths and weaknesses in predicting a weather event. MMEs combine forecasts from different models and provide additional and more reliable information compared to a single model. Different MME approaches have been attempted by the weather forecasters and researchers, namely,. poor-man ensemble or simple mean and weighted mean. In poor-man ensemble, mean of multiple forecasts is considered as the final forecast, whereas in weighted mean, based on the previous knowledge of the model forecast skill, weights for each model are computed. Using these weights weighted mean is computed. It has been seen that the weighted mean approach outperforms the simple mean in forecasting rainfall.

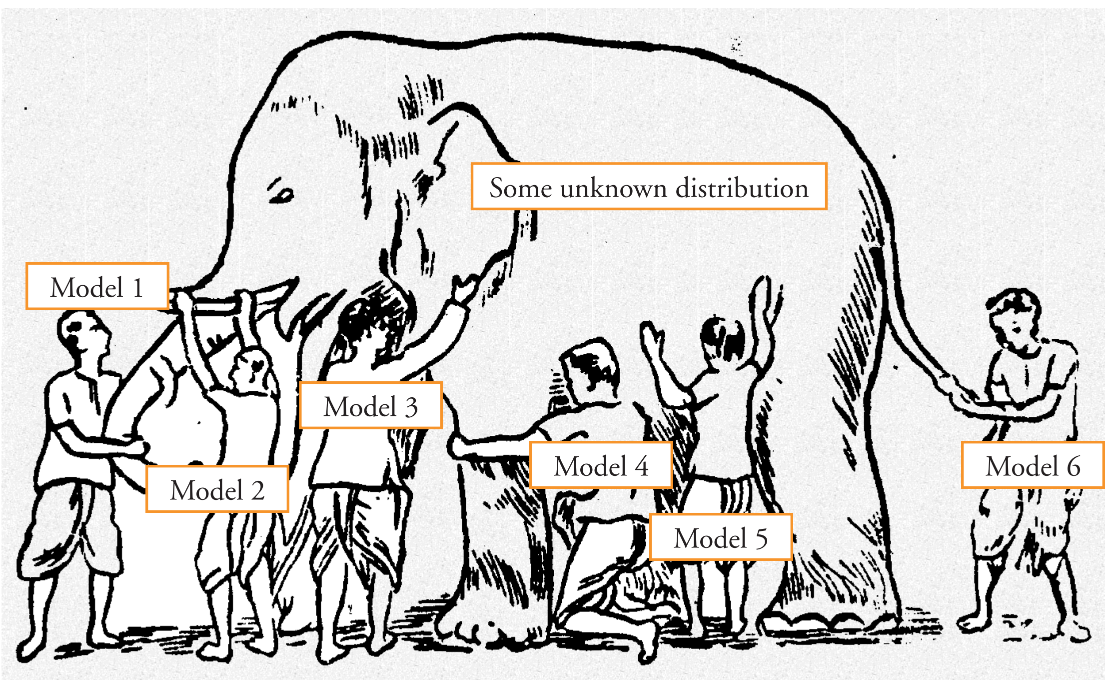

Figure 1: *Cartoon showing the concept of multi model ensemble approach.*

Now, the question is how to improve the forecasting skill further. In the present research work, an advanced MME approach has been developed for enhancing the existing summer monsoon rainfall forecasting skill. In carrying out the study, five models from different forecasting agencies were considered. These models were selected because of their higher skills in capturing the summer monsoon features. For assessing the skill of model forecasts the rain gauge based rainfall data available from India Meteorological Department (IMD) over the Indian landmass has been used. This data set is derived from a daily record from about 7000 rain gauge stations spread across the country incorporating the necessary quality checks. Quality checks simply mean verifying the location information of the gauge station, checking for missing data, etc. In order to forecast the SW monsoon rainfall, the Indian region was divided into small regions called grids (in the present study each grid corresponds to 25km x 25km area). The forecasts were formulated for 24, 48, 72, 96 and 120 hours (1-5 days ahead) over the Indian landmass.

The first step was to bring out the limitations of conventional MME approaches. The conventional approaches either assign same weight to each model or the weights are based on the past performances of the models. The weather is highly dynamic, therefore, calculating weights for each model only once using large set of past data, ignores this dynamic behaviour of weather. Also the models get upgraded from time-to-time, which is again a dynamic process that affects their forecast skill. Such changes are important to be taken into account while computing the weights for each model as the weights are the backbone of the MME approach and is the key point to be improved upon. Next, question was, how many days should be taken for computing weights. Further, the forecasts from even the best model can often go quite wrong due to the chaotic nature of the atmosphere. This trait of varying performance of models is ignored by the existing MME approaches, as they select all the participating models which degrade the overall performance thereby underestimating the performance of the better performing models.

The newly developed approach overcomes these limitations by dynamical selection of models based on their performance in the recent past, therefore, 45 days (chosen from the summer monsoon season, namely, June to September). The minimum forecast error was achieved by using 45 days, which became the basis for the selection of 45 days in order to weight the models. Unlike conventional MME approaches, the dynamical model selection approach makes a choice from the combination of only three better performing models from the five participating models. The selection is based on the higher correlation between the rainfall values forecasted by the models and observed values obtained from the IMD rain gauge rainfall product. Due to the varying skill of each model at different places and forecast hours, the model selection procedure is carried out at each region and for each forecast hour, hence, the three selected models change for every region as well as for each forecast hour.

To verify the method's accuracy, forecasts were checked against IMD rainfall data from 2008 to 2013.Results show an improvement of around 6-10% for 24-120 hour forecasts using dynamical model selection approach compared to the existing approaches. The point worth noting was that the improvement increased with the forecast lead time. The newly developed method has shown sufficiently promising results for real time dissemination of the forecasts to the user community.

Due to the inherent chaotic nature of the atmosphere, the precise prediction of the accurate amount and position of rainfall still remains a challenge to the scientific community, but this uncertainty in nature is what attracts the scientists and researchers towards this research field. It reminds me of the words from Edward Lorenz, pioneer of the chaos theory that, "If atmospheric processes were constant, or strictly periodic, describing them mathematically would be easy. Weather forecasting would be easy, and meteorology would be boring."