The inscrutable monsoon?

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The monsoon of 2016 has been an intriguing one. With two droughts in a row (2014 and 2015) hope was running high for a good monsoon. Indeed, all portents at the beginning of the monsoon appeared to be good. Most major forecasting centres predicted the end of El-Niño, a warming in far-off equatorial Pacific that is known to be associated with weakening of monsoon rainfall, and the return of the La-Nina, the cold phase over equatorial Pacific that has been observed to be associated with higher monsoon rainfall. Most models, both statistical and numerical, indicated a strong monsoon. The first stage forecast of IMD issued on 12 April, indicated high probability of near-to-above normal monsoon and quantitatively predicted the monsoon to be at 106% (with error of ±5%) (Figure 1) of its long period average (LPA). A private forecasting agency too proclaimed the advent of a strong monsoon (in April 2016 it predicted 105% of LPA with error of ±4%, http://www.skymetweather.com/content/weather-news-and-analysis/skymet-weather-foreshadows-above-normal-monsoon-for-india-in-2016/). Numerical models too indicated a strong monsoon (e.g. 111% with an error range of ±5% by the numerical model developed under the national monsoon mission). The second stage forecast of IMD revised the target upward with only 4% chance of below normal monsoon and 30+ per cent chance of rainfall of being greater than 110% (termed as 'excess' monsoon). Quantitatively the 2nd stage IMD forecast indicated a mean rainfall of about 106% with 4% error.

This year, the monsoon started late with onset over Kerala around 8 June and was generally weak in the month of June. All-India averaged rainfall for June was about 11% below normal. July saw a resurgence in rainfall with many parts of the country receiving excess rainfall and with an overall rainfall about 6.6% in excess of its LPA. However, rainfall in August was below normal (8.9% deficit). A sustained strong active spell of rain over major parts of the country that could have improved the monsoon strength was missing. Many hoped that September would again see a resurgence but it was not to be (a deficit of more than 3%). The monsoon season of 2016 ended up below-normal by about 2.9% (see Figure 1).

What went wrong with the monsoon and its forecasts? The causes for this could be many and would need many a post-mortem to determine them. But most climate scientists are unanimous about one phenomenon: the failure of appearance of La-Nina. While the equatorial Pacific cooled from one of the strongest El-Niños in the recent past, the cooling was not strong enough to turn into a La-Nina. Many climate-pundits attribute this unexpected failure to be the major cause of a weakened monsoon.

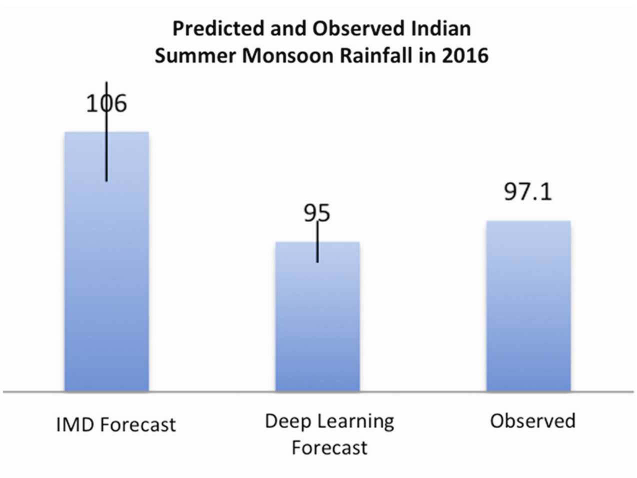

Figure 1. The predicted and observed rainfall during summer monsoon season of 2016 over India. All values are in percentage of long-period average. The vertical lines on top of the two forecast products indicate the uncertainty estimated by these models.

Currently, most empirical models employed in monsoon forecasting use regression techniques to build up relationships. Developing empirical models essentially is an exercise in determining relationships in observed data. In the recent past with increasing amounts of data available in every walk of life, much research is being persued in the field of data analytics. A new field called deep learning technique has evolved to determine patterns in large datasets. Deep learning is based on a set of algorithms that analyse data to generate high-level abstractions. The method uses a deep graph and can have multiple processing layers which could be composed of nonlinear and linear transformations (https://en.wikipedia.org/wiki/Deep_learning). Many search engines use deep learning techniques. Recently Saha *et al.*[1,2] have proposed a new monsoon prediction model based on auto-encoder technique (a deep learning alogrithm). The model uses past behaviour (ranging from about a month in advance, to a year in advance of the predicted monsoon season) of parameters such as temperature of the ocean surface, mean sea-level pressure, winds and air temperature. The variables themselves are similar to those used by IMD in its statistical models. The difference being in combining them through deep learning algorithms. The auto-encoder is an unsupervised learning algorithm (no human intervention) that picks up patterns and associations between monsoon rainfall and other parameters over the entire globe. The predictors so developed are checked for their association with the monsoon and used in a multi-stage neural network to obtain predictions. During the testing period of 1994–2014, the single-layer auto-encoder based technique captured all the extreme years with mean absolute error of about 4.5%. Stacked (multi-layer) auto-encoder had error of about 4% (ref. 2). In comparison, the absolute error for IMD models during the same period was about 6%.

How did deep learning methods fare for 2016? Ensemble prediction made with single layer auto-encoder models[1] showed the deficit to be about 10% (with error margin of 4%). Forecasts made with an ensemble of stacked-encoder model[2] in May indicated that the monsoon would be below normal (about 95% of its long-term mean with an error of about 2.1%) (Figure 1).

Deep learning technique seems to show a lot of promise and could be used in operational forecasts. It is not suggested that use of numerical models should be discouraged. Numerical models have improved quite significantly, especially in the short range (up to 3 days) and in the medium range (5–15 days). However on seasonal scales, their skill while steadily improving is only comparable to empirical models. In the meanwhile, strides made in fields such as deep learning should not be ignored. A good prediction of monsoon could be as important as a good monsoon for the Indian economy.

1. Saha, M. *et al.*, *Meteorol. Atmos. Phys.*, 2016a; doi:10.1007/s00703-016-0431-7.
2. Saha, M. *et al.*, *Theor. Appl. Climatol.*, 2016b (under revision).

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