

## Forecasting the Indian monsoon

Editor's note :

We received a letter from C. K. Gopinathan of the National Institute of Oceanography stating that he was planning to write an article, 'On the forecast of a normal summer monsoon rainfall during 1990', to be considered for publication in the 'Opinion' section, and asking if it could appear before June. Gopinathan also stated that if it appeared after June, it would not have much value. We replied that the article would be considered for publication after the usual review procedure. The article by Gopinathan and J. S. Sastry, which disputes the 1990 monsoon forecast of V. Gowariker, V. Thapliyal and others, and some of the methods used, arrived in the middle of April.

The referee suggested that the article could be published in the 'Scientific correspondence' section, provided Gowariker et al. were given an opportunity to reply. We sent the article to Gowariker and Thapliyal, who then sent their reply, and added that, while they were reluctant to enter into any controversy regarding their work, they saw it fit to reply to the criticism of Gopinathan and Sastry on purely technical grounds, especially because it would be published in *Current Science*. We scheduled both notes in the 25 April issue, which, unfortunately, has been delayed.

To our surprise we found that Gopinathan had given an interview to a newspaper, criticizing the work of Gowariker et al., before their comments and Gowariker et al.'s reply could appear in *Current Science*.

We are aware that this is a free country and that it is an individual's privilege to publish in a newspaper. But that is not the scientists' ethic. Unless Indian scientists learn to follow strictly the code that scientific controversies must be discussed and resolved in scientific journals, our science will be doomed. Once the views are published in a scientific journal they become public knowledge and can then appear in the media, provided the picture given is a fair one.

In view of Gopinathan's interview to a newspaper we had no choice but to release the rejoinder of Gowariker and Thapliyal before its appearance in print in these columns.

The note by Gopinathan and Sastry and the reply by Gowariker and Thapliyal appear below.

The success of two long-range forecasts of the Indian summer monsoon rainfall issued by scientists of the Department of Science and Technology (DST) just before the seasons during 1988 and 1989 seems to have encouraged them to issue another extra-long-range forecast of normal Indian rainfall in February 1990. The need for forecasting the succeeding monsoon by February is understandable, as the Government has to make suitable provisions for drought relief in the budget, in case the succeeding monsoon is likely to be bad. In this respect, a forecast of the summer monsoon rainfall issued before the budget is more useful than the one normally issued in June. However, there are other aspects of the forecast which merit a discussion. We examine here the success of the two earlier long-range forecasts, and present a view that the present long-range forecast of a normal monsoon rainfall for 1990 may prove wrong.

Long-range forecasting of summer monsoon rainfall has a long history. It started with the forecast of Blandford on 4 June 1886. The initial forecasts were for the whole of British India. This practice was continued for some time. Later, G. Walker, after his studies on the variability of Indian rainfall, identified a number of regions with similar

rainfall characteristics. He started separate forecasts for NW India, NE India and Peninsular India in 1924. The forecasts for NE India were discontinued after 1935, since the interannual variability was well within the normal forecast accuracy limits of  $\pm 10\%$  of the long-term mean. There were separate forecasts for NW India and Peninsular India till 1988, when the practice was changed to an all-India forecast. The earlier practice of region-wise forecasting is more meaningful as the standard deviation of seasonal percentage departure from normal is about 22.4% for NW India, 13.5% for the Peninsula, 7.2% for NE India, and 12.5% for the whole of India. The attempt from 1988 is to predict the average rainfall throughout the country, which includes the highly unpredictable NW region and the least variable NE region. This is much easier than what was attempted earlier and a step backward to pre-1924 status. It is good to predict the all-India rainfall, but it will be better if rainfall variation in regions where it is highly variable can also be predicted; still better if month-wise forecasts could be made.

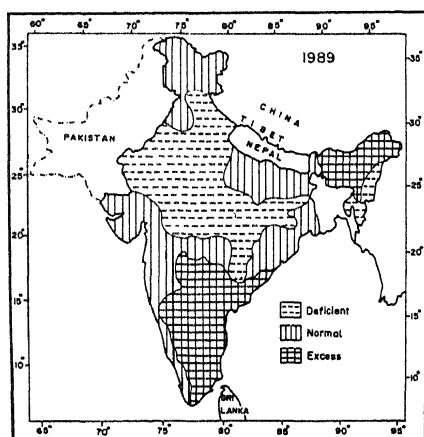
There is some confusion on the use of qualifiers such as 'normal', 'good' and 'bad' when applied to rainfall statistics. The practice of the India Meteorological

Department (IMD) was to consider rainfall within  $\pm 10\%$  of the long-term mean as normal for the regions and rainfall within  $\pm 19\%$  of the long-term mean as normal for the subdivisions. This is equivalent to an assumption that rainfall will be normal 50–60% of the time in the regions and 38–99.7% of the time in the subdivisions, depending upon the standard deviation for the subdivision. The result of this practice is that rainfall will be normal nearly all the time in subdivisions where the standard deviation is low.

It appears reasonable to define 'normal' in terms of standard deviations for India as a whole, for regions, and for subdivisions. In the present discussion, 'normal rainfall' is defined as that within  $\pm \frac{1}{2}$  the standard deviation of seasonal percentage departure from the long-term mean. This is equivalent to the assumption that rainfall will be normal 38% of the time. This criterion may be applied to all-India as well as to regional and subdivisional levels. The rainfall is 'excess' when the percentage departure from the normal is above this defined normal, and 'deficient' when it is below. A 'good' or 'bad' monsoon has to take into consideration the percentages of areas receiving normal, excess or deficient rainfall also. A year may be considered as a 'good' monsoon year

when more than two-thirds of the country gets excess or normal rainfall, and 'bad' monsoon year when more than two-thirds of the country gets deficient rainfall.

The official prediction of a normal monsoon for the 1989 season was statistically correct. The areas of the subdivisions that received normal, excess and deficient rainfall during the 1989 summer monsoon season, according to our definition, are shown in Figure 1. The figure is based on operational data from IMD and may change slightly when the correct figures are available. The pattern is strikingly similar to the pattern of the third principal component that emerged from the EOF analysis of Indian rainfall series by Bedi and Bindra<sup>1</sup>. The rainfall was fairly low in NW and central India (in the monsoon trough region) and fairly high in the SE region. The all-India rainfall is normal when we take the average of all the regions. However, it is not a realistic assessment of the actual rainfall situation during the 1989 monsoon. There are certain years when rainfall is excess, deficient or normal nearly all over India. There is something subnormal with the 1989 all-India rainfall pattern and it was definitely not a good monsoon year.



The forecasts of summer monsoon rainfall issued by meteorologists of DST during the last two years were based on 16 parameters and three models. The best of their models, the power regression model, has an accuracy of  $\pm 4\%$ . The root mean square error in the forecast by the two-parameter formula of Shukla and Mooley<sup>2</sup> is claimed to be only 4.2%. The inclusion of a number of additional parameters has not improved forecast accuracy considerably.

In their parametric model, Gowariker *et al.*<sup>3</sup> considered a year as a drought year when the all-India rainfall deviated more than 10% from the long-term mean. All other cases were considered as normal years. Because of such a definition, rainfall will be 'normal' in three out of four cases on a long-term basis, as seen from data given by them from 1951 to 1988. The parameters are used to predict the group in which a particular year will fall.

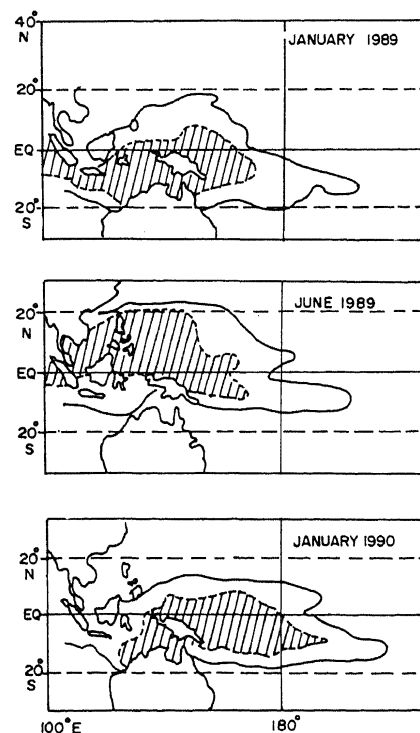
A usual difficulty in using a large number of parameters for long-range forecasting is that of cross-correlation between the parameters. It appears to us that all the 16 parameters considered for the forecast are related to a fewer number of factors or phenomena. Walker had earlier noticed that an increase in the number of parameters does not enhance the accuracy of a forecast using a multiple regression equation. We feel that this observation is applicable to both multiple regression models and power regression models.

One of the major problems in long-range forecasting of Indian rainfall is that we have not fully understood the physical mechanisms causing excess/deficient rainfall. In February 1990, when the present forecast was made, data on several of the 16 parameters, including important ones like the 500-mb ridge position and the Darwin pressure anomaly, were not available. The forecast must have been made from data on a few parameters, and perhaps the tendencies of the rest of the parameters. Moreover, the atmospheric parameters are known to have poor persistency. While the attempt is good and is based on data for a number of parameters, we think that the present forecast, unless modified later, may not stand the test of time.

Our opinion, that the Indian rainfall during 1990 may be below normal, is based on the insight we have gained through the study of the ocean-atmosphere interaction over the Pacific Ocean and its influence on Indian rainfall. We feel that the Pacific Ocean exerts a great influence on Asiatic monsoon rainfall in general. It may be noted that six out of the 16 parameters considered for the present long-range forecasting of Indian rainfall are related to El Niño/Southern Oscillation (ENSO), a Pacific Ocean phenomenon.

We have observed an interesting

relationship between the orientation and spread of the Pacific Ocean Warm Pool (POWP, areas of the Pacific Ocean where the sea surface temperature is more than 29°C) and Indian rainfall<sup>4</sup>. The position of POWP is also related to the ENSO phenomenon. In our opinion, POWP is the link between Asiatic monsoon and ENSO, since both depend upon the position of POWP in the Pacific Ocean. Our study shows that the Indian rainfall is less when POWP is located farther away from the Indian subcontinent and more when it is nearer. About 64% of the variability of the monthly Indian rainfall is explained by the position of POWP. The positions of POWP during January 1989, June 1989 and January 1990 are given in Figure 2 (hatched areas). The position in January 1990 was already east of the January 1989 position. As POWP shifts or spreads eastward, the atmospheric circulation over the Indo-Pacific region tends to change from predominantly Walker-type to predominantly Hadley-type. Such a change has an adverse impact on Indian rainfall pattern. Because of the persistent nature of the oceanic changes, there is a high probability that it may shift/spread further to the east during the coming monsoon season. Therefore, the central equatorial Pacific Ocean is likely to be warmer in summer 1990 than it was during the summer of 1989, and hence Indian summer monsoon rainfall in 1990 will



probably be below normal. The rainfall pattern may be similar to that in 1986, or perhaps even to that in 1982, when the all-India rainfall was less than normal by about 10% and 13% respectively.

1. Bedi, H. S. and Bindra, M. S., *Tellus*, 1980, 296.
2. Shukla, J. and Mooley, D. A., *Mon. Weath. Rev.*, 1987, 695.
3. Gowariker, V. *et al.*, *Mausam*, 1988, 115.
4. Gopinathan, C. K., *Curr. Sci.*, 1988, 1163.

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reply:*

Gopinathan and Sastry (GS) have expressed the opinion that the success of two long-range forecasts (1988 and 1989) has encouraged DST/IMD to issue extra-long-range forecast of monsoon rainfall for 1990 as early as in February. Research on long-range forecasting is a continuous process in DST/IMD and the extra-long-range forecast is based on the encouraging results of subsequent work.

The forecast of a below-normal monsoon in 1990 by GS is based on data on a single parameter (migration of warm water pool) for 8 years (1982-1989) and has obvious limitations. It is well known that over a long period of time no parameter exhibits one-to-one relationship with the Indian monsoon rainfall; the correlation coefficient between a parameter and monsoon rainfall has in the past changed not only in magnitude but also in sign. Therefore inclusion of a larger number of *physically linked parameters* has the inherent advantage of maintaining forecast accuracy at a reasonable level. This has led to the development of different forecast techniques, like multiple screening regression,

power regression, dynamic stochastic transfer and parametric model.

GS have expressed reservations about the use of 16 parameters in the power regression model. These parameters are physically linked with the monsoon. Besides the statistical significance of individual parameters, there are several other reasons for inclusion of all the 16 parameters in the power regression model. Our parametric model uses the parameters for the forecast in two stages. First the data on the 16 parameters are assessed qualitatively as favourable or unfavourable, in each case, and a qualitative forecast is prepared. Secondly a quantitative forecast is formulated. For this purpose all the 16 parameters are used in the power regression model. To achieve this<sup>1</sup>, various experiments were carried out and it was found that the best-fit model is achieved when all the 16 parameters are arranged in the order of magnitude of their correlation coefficients with the monsoon rainfall. In this process the variance explained by successive parameters goes on decreasing but the addition of every parameter explains some additional variance, which ultimately contributes to the accuracy of the forecast. Regarding the comment of GS on model errors, we wish to state that the same model can have different root mean square errors for different periods of time. Thus comparison of errors obtained from two models has no relevance in judging the accuracy of a model in independent real-time situations.

GS have also suggested that limits of  $\pm \frac{1}{2}$  the standard deviation may be considered for defining normal monsoon rainfall. In our opinion there is no hard and fast rule for framing such a definition. The definition suggested has inherent limitations like any other definition. Keeping in view the variability of monsoon rainfall and the predictive power of the long-range forecast of Indian monsoon rainfall, the definition of normal monsoon used in our paper remains valid and in fact is widely used.

GS state that our 1989 forecast was not correct. This is not borne out by the facts. Our forecast indicated that the

monsoon rainfall over India as a whole during the 1989 monsoon season was likely to be 102% of the normal, with model error of  $\pm 4\%$ . The observed monsoon rainfall in 1989 was 101.4% of the normal. GS have suggested that a year may be considered as a good monsoon year when more than two-thirds of the country gets excess or normal rainfall. Even by the criterion suggested by them, our 1989 forecast has been validated as more than 80% of the country received normal or above-normal rainfall during monsoon 1989 (Figure 1 of GS needs some corrections in view of data from more stations). The authors' contention is thus not borne out by the facts.

GS also feel that issuing a forecast only for the country as a whole is a retrograde step. We do not agree with this view. With the development of the parametric and power regression models, it has become possible, for the first time, to judge the limits of confidence assignable to a particular year's forecast. In the past 39 years, when more than 70% parameters were favourable monsoon rainfall for the country as a whole has been found to be on the positive side of normal. In addition, with the development of these two models for long-range forecast of monsoon rainfall over India as a whole, the accuracy of the forecast has been found to be higher compared to forecasts that can possibly be issued at this stage for larger divisions of India. In view of this, it is worthwhile to issue a long-range forecast of higher accuracy so that users have confidence in the forecast and use it. Research is under way at IMD to develop similar forecast models for larger divisions of India also.

1. Gowariker, V. *et al.*, *Mausam*, 1988, 115.

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