IMD's new operational models for long-range forecast of southwest monsoon rainfall over India and their verification for 2003

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In 2003, India Meteorological Department (IMD) introduced several new models for the long-range forecast of the southwest monsoon rainfall. With this, it has become possible to issue the long-range forecasts in two stages. On 16 April, IMD issued the forecast for the 2003 southwest monsoon rainfall for the country as a whole, giving its users an extra lead time of about 40 days. On 9 July, IMD issued a forecast update and additional forecasts for three broad homogeneous regions of India. It also gave a five-category probabilistic forecast. In view of its importance for agriculture, for the first time, IMD also issued a forecast for July rainfall. The development of the new models is discussed in this article. The forecasts issued operationally in 2003 using these new models have proved to be accurate.

THE India Meteorological Department (IMD) has been issuing long-range forecasts of the southwest monsoon rainfall since 1886. It was, however, the extensive and pioneering work of Gilbert Walker[1,2], who was the Director General of IMD from 1904 to 1924, that led to the development of the first objective models based on statistical correlations between monsoon rainfall and antecedent global atmosphere, land and ocean parameters. Since then, IMD's operational long-range forecasting system has undergone changes in its approach and scope from time to time. The 16-parameter power regression and parametric models developed by Gowariker *et al.*[3,4] were introduced operationally by IMD in 1988. A minor modification was made to the model in 2000, involving the replacement of four parameters, as with time they had lost their correlation[5]. The year 2002 turned out to be an all-India drought year with an overall rainfall deficiency of 19%, while IMD had predicted a normal monsoon, resulting in a lot of attention being focused on IMD's prediction methodology. In addition, over the recent series of successive normal monsoons over the country as a whole but with drought situations prevailing over many parts of the country, user demand had been building-up for an earlier forecast of the monsoon, a mid-season update, month-wise rainfall forecasts and for narrowing down IMD's definition of a 'normal' monsoon. This motivated us in 2003, to review the current long-range forecast models and attempt to develop new credible models which came closer to meeting the user requirements. The long-range forecasts for the 2003 monsoon based upon the newly developed models were issued by IMD on 16 April and 9 July 2003 and released to the public at press conferences. This article describes these new models and their verification using actual rainfall data available by the end of September 2003.

IMD's new long-range forecast models, like the previous ones, are statistical in nature. Statistical models have many inherent limitations[6–10]. The correlations between monsoon rainfall and the predictors can never be perfect. They may undergo epochal changes and there may be cross-correlations between the parameters[11,12]. Attempts to forecast monsoon rainfall over smaller areas like a district, or smaller periods such as a week or ten days, become unsuccessful as correlations fall drastically. The only way to do this is through dynamical atmospheric general circulation models with specified boundary conditions and varying initial conditions. As of today, globally, dynamical models do not have the required skill to accurately simulate the salient features of the mean monsoon and its variability. They are further hampered by the lack of data in the oceanic regions important to the monsoon. Routine outputs of dynamical models run by a few global prediction centres are available, but India-specific dynamical models need to be developed in order to achieve the type of accuracy demanded by Indian users. In the mean time, empirical/statistical methods will need to be developed and refined for generating long-range predictions of monsoon rainfall.

Development of new models for seasonal rainfall for the country as a whole

The performance of IMD's operational long-range forecasts of monsoon rainfall for the country as a whole since 1988 is shown in Figure 1. The long series of normal monsoons was correctly predicted qualitatively by the parametric model, but the quantitative forecasts derived from

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*For correspondence. (e-mail: rajeevan61@yahoo.co.in) the power regression model showed large deviations from the actual monsoon rainfall in many years. As a result, the root mean square error of the 16-parameter power regression model for the period 1988–2002 was 9%, which is more than twice the model error of 4%.

The year 2002 turned out to be a severe all-India drought year, and the entire monsoon season had many intriguing features[13], specially the fact that in July the country received only half of the month's normal rainfall. This situation could not be foreseen by any operational statistical or dynamical model[13].

The optimum number of predictors in a statistical regression model has been a matter of debate. There are studies[14,15] recommending that the predictors be restricted to as small a number as possible in such models. Our own assessment is that 8 to 10 predictors are required for explaining a good amount of variation (70–75%) in the model development period and also limiting the root mean square error of the results over the independent period to a minimum.

As part of the development of new power regression models for monsoon rainfall forecasts, every parameter in the 16-parameter model was examined for statistical stability over time by calculating running 21-year window correlations. The analysis revealed that all six April–May parameters and four winter–spring parameters showed weakening correlations. We therefore decided to remove these ten parameters from the set. We also carried out an extensive data analysis in an attempt to find more stable and physically related predictors for use in the long-range forecast model. This exercise yielded four new predictors, viz. NW Europe temperature in January[16,17], South Indian Ocean SST gradient index in March[18], South Indian Ocean zonal wind at 850 hPa in June and Nino 3.4 SST tendency AMJ–JFM.

A new parameter set consisting of six old and four new parameters was thus formulated for the purpose of further model development (Table 1). The 21-year moving correlations of the ten parameters are shown in Figure 2. All the correlations are found to be stable, especially over recent years.

In the new set of ten parameters, there are eight which become known by March end and two need data up to June. Using the subset of eight parameters and the full set of ten parameters, two new power regression models were developed. The power regression model has the following mathematical form

$$R = C_0 + \sum_{i=1}^{i=n} C_i X_i^{P_i},$$

where R is the rainfall, Xs are the predictors, and Cs and

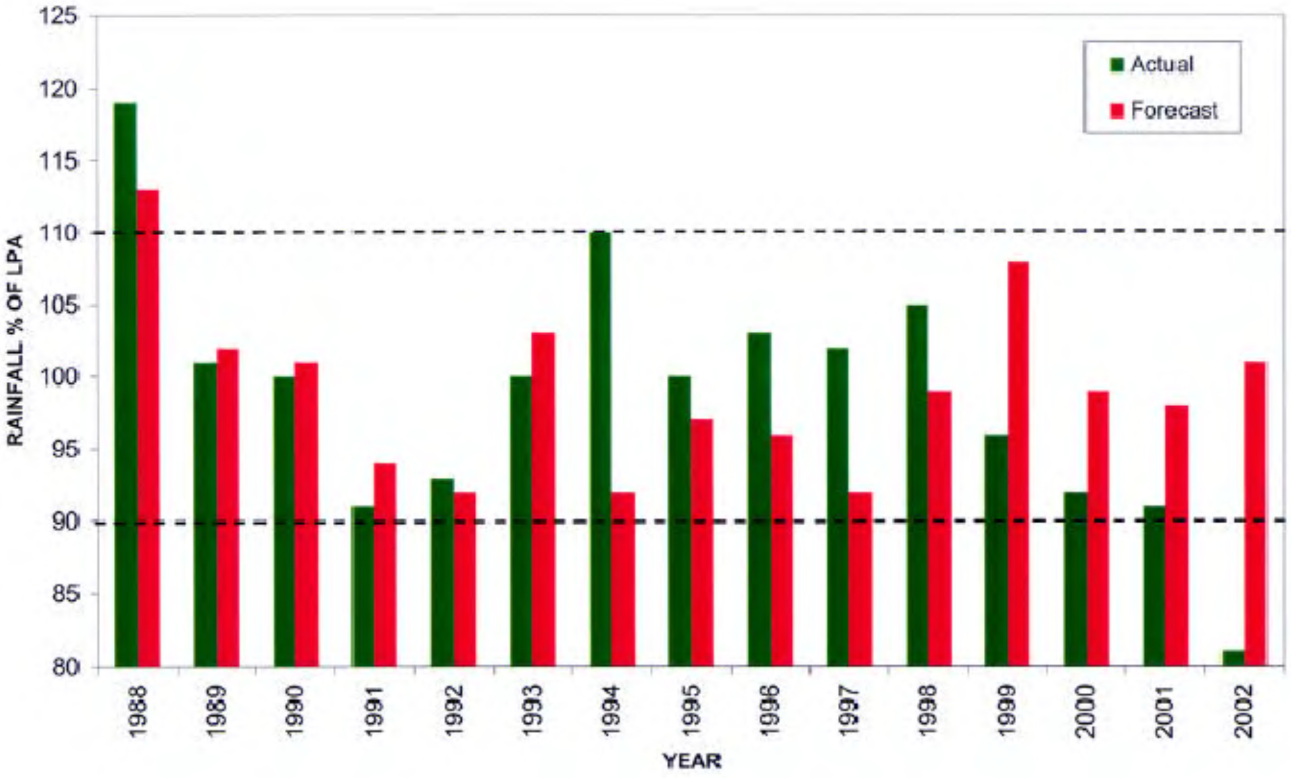

Figure 1. Performance of operational forecasts during the period 1988–2002. Actual (forecast) in percentage of long period average (LPA) is shown in green (red).

*P*s are constants. *N* is either 8 or 10. In the mathematical formulation used in the 16-parameter model, various constants like α and β were used to scale the value of the parameters. In our formulation, we have standardized the predictors before using them in the above equation. The model is nonlinear and the power term *P*, in the above equation varies between + 2 and – 2. In the 16- parameter model, the power term varied between + 4 and – 4, which allowed far greater nonlinearity.

The new 8-parameter and 10-parameter models were developed using data of 38 years (1958–95). Another seven years' data (1996–2002) were used for independent verification of the models. The performance of the new 8- and 10-parameter models as compared with IMD's opera-

Table 1. Parameters identified for the model development

No.	Parameter	Old/new parameter	Month	Correlation coefficient (period: 1983–2002)
For 8 and 10-parameter models				
P1	Arabian Sea SST	Old	Jan., Feb.	0.55
P2	Eurasian Snow cover	Old	Dec.	– 0.46
P3	NW Europe temperature	New	Jan.	0.46
P4	Nino 3 SST anomaly (previous year)	Old	Jul.–Sep.	0.42
P5	South Indian Ocean SST Index	New	Mar.	0.47
P6	East Asia pressure	Old	Feb., Mar.	0.61
P7	Northern Hemisphere 50 hPa wind pattern	Old	Jan., Feb.	– 0.51
P8	Europe pressure gradient	Old	Jan.	0.42
For 10-parameter model				
P9	South Indian Ocean 850 hPa zonal wind	New	Jun.	– 0.45
P10	Nino 3.4 SST tendency	New	Apr.–Jun., Jan.–Mar.	– 0.46
For other models				
P11	South Indian Ocean SST index	New	Mar., May	
P12	North Indian Ocean–North Pacific Ocean 850 hPa zonal wind difference	New	May	
P13	North Atlantic Ocean SST	New	Dec., Jan., Feb.	

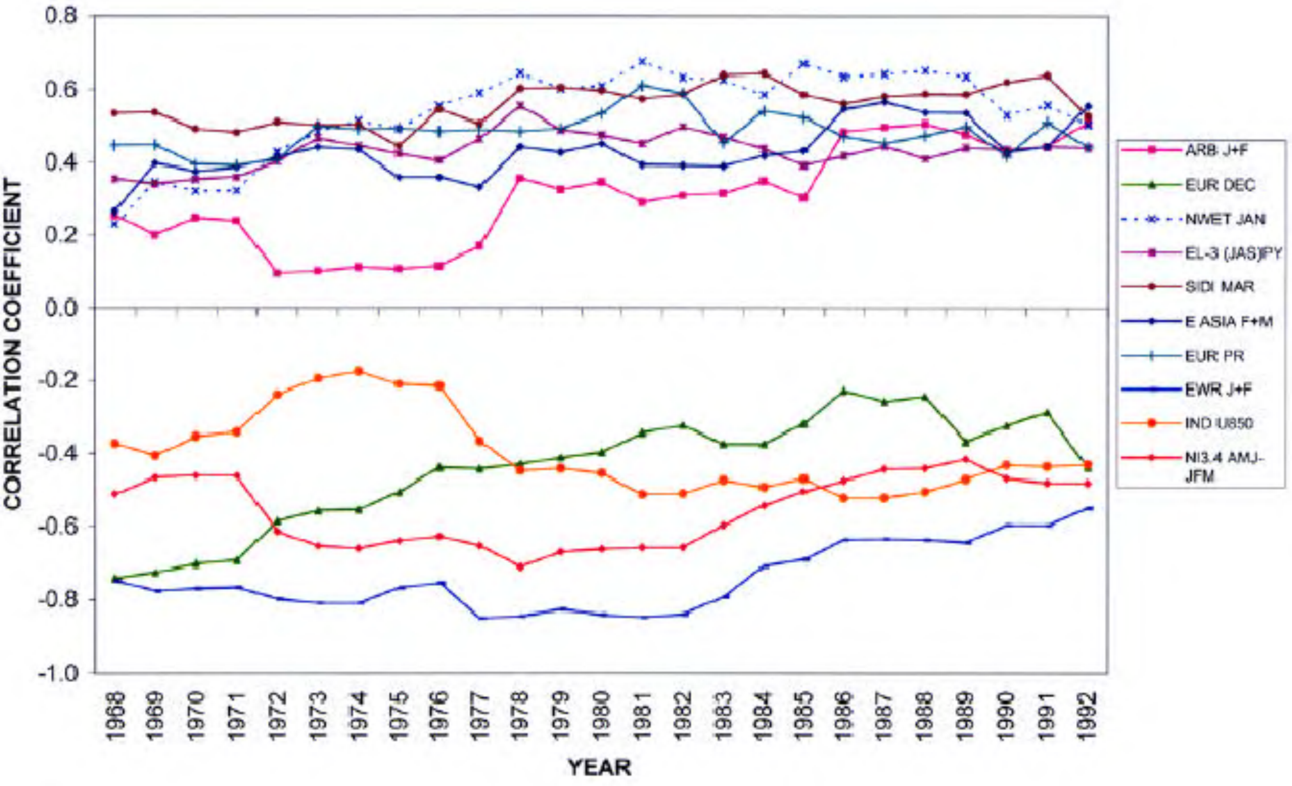

Figure 2. Twenty-one-year moving correlations of the ten parameters with southwest monsoon rainfall (June–Sept). The year indicates the central year of the 21-year period.

tional forecasts issued with the 16-parameter model during the independent verification period is given in Table 2. A similar comparison for the model development period is given in Table 3. The real test of a statistical model is in its performance during the independent verification period rather than during the model development period. It is clear that the new 8- and 10-parameter models have generated forecasts that are much closer to actual rainfall than those which were made operationally during the independent verification period. The root mean square error of the operational forecasts during the period 1996–2002 was 11%, while that of the new 8- and 10-parameter models for the same period was 7 and 6% respectively. The model errors of the 8- and 10-parameter models are 5 and 4% respectively, which is of the same order as that of the 16-parameter model at its inception. The performance of the 8- and 10-parameter models is also shown in Figure 3 *a* and *b* respectively. It may be mentioned here that both the new models have not been able to correctly bring out the large rainfall deficiency in 2002, but generally their performance has been better in other drought years in the hindcast mode.

Table 2. Comparison of performance of 16-, 8- and 10-parameter models (error % = actual rainfall % – forecast %) during independent validation period (1996–2002)

Year	16-parameter model	8-parameter model	10-parameter model
1996	+ 7	+ 3	+ 3
1997	+ 10	0	+ 1
1998	+ 6	– 6	– 3
1999	– 12	– 6	– 7
2000	– 7	1	0
2001	– 7	0	0
2002	– 20	– 18	– 15

Table 3. Comparison of performance of 16-, 8- and 10-parameter models (error % = actual rainfall % – forecast %) during model development period (1958–95)

		16-parameter model		New 8-parameter model		New 10-parameter model	
Year	Actual %	Forecast %	Error %	Forecast %	Error %	Forecast %	Error %
1958	110	110	0	112	– 2	112	– 2
1959	114	117	– 3	115	– 1	117	– 3
1960	101	104	– 3	100	1	103	– 2
1961	122	120	2	115	7	114	8
1962	97	97	0	102	– 5	102	– 5
1963	98	97	1	96	3	97	1
1964	110	111	– 1	116	– 6	116	– 6
1965	82	82	0	86	– 4	84	– 2
1966	87	90	– 3	89	– 2	89	– 2
1967	100	102	– 2	102	– 2	102	– 2
1968	90	85	5	84	6	86	4
1969	100	98	2	102	– 2	102	– 2
1970	112	110	2	108	4	107	5
1971	104	99	5	102	2	102	2
1972	76	76	0	77	– 1	76	0
1973	108	108	0	103	5	104	4
1974	88	92	– 4	86	2	85	3
1975	115	118	– 3	108	7	106	9
1976	103	102	1	94	9	94	9
1977	104	102	2	105	– 1	105	– 1
1978	109	107	2	98	11	102	7
1979	81	82	– 1	84	– 3	85	– 4
1980	104	108	– 4	104	0	104	0
1981	100	104	– 4	106	– 6	102	– 2
1982	86	91	– 5	86	0	88	– 2
1983	113	113	0	109	5	108	5
1984	96	100	– 4	103	– 7	102	– 6
1985	93	99	– 6	98	– 5	95	– 2
1986	87	88	– 1	91	– 4	90	– 3
1987	81	79	2	80	1	79	2
1988	119	113	6	116	3	117	2
1989	101	102	– 1	102	– 1	104	– 3
1990	106	101	5	105	1	107	– 1
1991	91	94	– 3	95	– 4	91	0
1992	93	92	1	104	– 11	104	– 11
1993	100	103	– 3	107	– 7	105	– 5
1994	110	92	18	100	11	100	10
1995	100	97	3	105	– 5	105	– 5

A particular advantage of having two power-regression models is that the first forecast can be generated in April itself with the 8-parameter model. Previously, IMD's

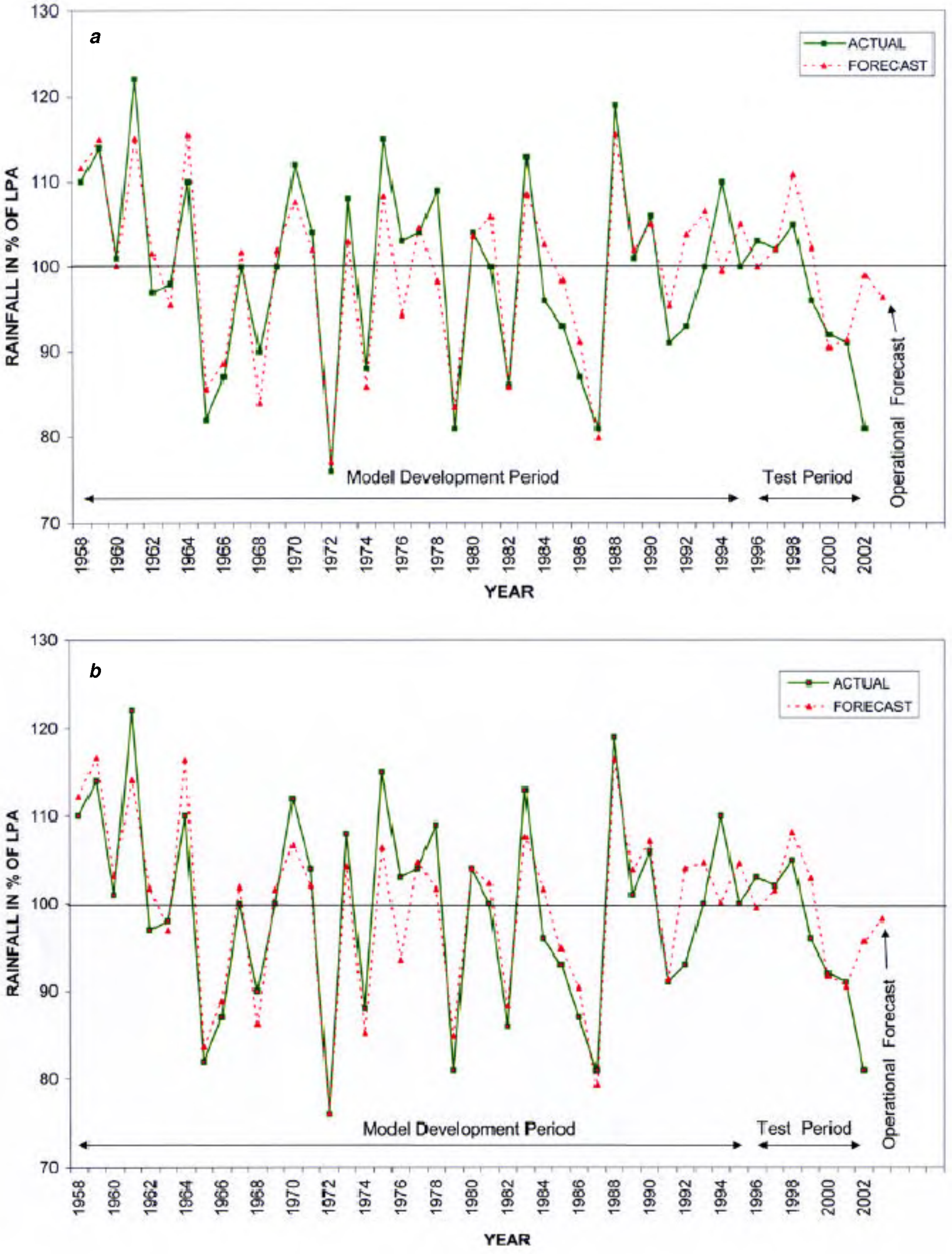

Figure 3. Performance of ***a***, 8-parameter power regression model and ***b***, 10-parameter power regression model. Actual (forecast) in percentage of LPA is shown in green (red).

forecast users had to wait until 25 May as the 16-parameter model required data up to the end of May. They can now get the forecast with a much longer lead time. Further, while factors such as the El Nino are known to exert a concurrent influence on the monsoon, IMD did not have a system of updating its forecast once it was issued on 25 May. The new 10-parameter model provides this flexibility for fine-tuning the April forecast on the basis of developments in June, particularly the El Nino/La Nina tendency. This is important because El Nino predictions made by global centres show wide differences and do not always come true, as was the case in 2003.

While the 16-parameter power regression model predicted the departure of monsoon rainfall from the long period average (LPA) in quantitative terms, the parametric model provided a qualitative indication of whether the coming monsoon would be normal or not. For purposes of definition, the season's rainfall for the country as a whole between 90 and 110% of the LPA was considered as normal, rainfall below 90% of LPA was regarded as deficient and rainfall above 110% was termed excess. It would be worth noting that in the period 1901–2002, there were 69 years in which the overall monsoon rainfall was in the normal category as defined above and there were 20 all-India drought years. Therefore, in a climatological sense, in any given year the probability of normal rainfall is about 70%, while the 20% probability of drought is far from negligible. It has also been seen that the agricultural and economic repercussions of the 91% rainfall may be significantly adverse compared to those of the 109% rainfall, even though both are clubbed in the normal category. We therefore felt that even within the broad category of normal rainfall, there was a need to give a probabilistic indication of the rainfall being in three narrower categories of near normal, below normal and above normal. We accordingly decided to develop models which can provide the probabilities of rainfall in five different categories ranging from drought to excess rainfall.

The new probabilistic models are based on the linear discriminant analysis (LDA) technique[14,19–22] and the same sets of eight and ten parameters previously defined are used. This technique, first introduced by Fischer[23], is now being commonly used in probabilistic statistical climate prediction[14].

A prerequisite of the LDA model is that each category may have equal prior probability. In our models, the five categories of rainfall were so defined as to have equal prior probability of 20% (Table 4). The models were developed with 40 years of data (1958–97), and data for five years (1998–2002) were used for model verification. We have first made a principal component analysis (PCA) of the eight and ten variables and selected three significant principal components (PCs) as predictors. In this case, PC1, PC3 and PC5 were used as predictors to satisfy the relationship between the sample size, number of variables and number of groups[22].

The discriminant model is a useful one for discriminating between different categories and estimating the probability for each category. In hindcast mode, the 8- parameter LDA model showed 68% correct classifications, whereas the 10-parameter LDA model showed 78% correct classifications. In hindcast again, both the LDA models correctly gave the highest probability of drought in 8 out of 9 actual drought years during the period, except in 2002 (Table 5) and no false alarms of drought were generated in any other years. This significant strength of the new probabilistic models has greatly enhanced the level of confidence with which IMD can now issue its long-range forecasts of the monsoon.

Development of a model for July rainfall for the country as a whole

July is the rainiest month of the southwest monsoon season and the normal rainfall in July for the country as a whole accounts for 33% of the monsoon season's total rainfall. There is also a good statistical association between July rainfall anomalies and the seasonal (June–September) rainfall anomalies[13]. Out of the four monsoon months of June to September, lack of rain in July has the most critical impact on agriculture, as sowings cannot be delayed any further and crops already sown cannot withstand the acute water stress. The severe drought in 2002 was due to the unprecedented deficient rainfall (– 51%) in July 2002, which brought down the kharif crop production by 30 million tonnes below that of the previous year.

Table 4. Category of monsoon rainfall for probability forecasts

Category	Rainfall range
Drought	Less than 90%
Below normal	90–97%
Near normal	98–102%
Above normal	103–110%
Excess	Above 110%

Table 5. Hindcast probability of drought indicated by the LDA model

	Probability (%)	
Year	8-parameter LDA model	10-parameter LDA model
1965	92	96
1966	91	78
1972	89	99
1974	77	66
1979	97	99
1982	79	89
1986	51	55
1987	96	99
2002	20	4

To develop a model for July rainfall, we had taken up an extensive analysis of July rainfall variability and associated circulation features. In this process, from a preliminary pool of 15 potential parameters, a set of eight parameters was finally chosen for model development after carefully analysing their statistical stability (Table 6).

An 8-parameter power regression model for July rainfall was developed on the same lines as that for the season's rainfall, using data of 38 years (1958–95) and an independent verification was carried out with data for the subsequent seven years (1996–2002). The performance of the July model is shown in Figure 4. Although the model error is of the order of ± 9%, it is still smaller than the 14% standard deviation of July rainfall, and so the model is useful. Interestingly again, the model could not predict the large rainfall deficiency of 51% observed in July 2002. This particularly large deficiency of 51% is about three times the standard deviation and can therefore be regarded as a climate extreme, and hence beyond the scope of a statistical model. However, in the case of the other years of deficient July rains, a clear indication of rainfall deficiency could be obtained from the model in the hindcast mode.

Table 6. Predictors for July rainfall

Parameter (defined in Table 1)	Correlation coefficient (1958–95)
P11	0.39
P10	– 0.30
P9	– 0.45
P6	0.30
P2	– 0.45
P12	0.56
P1	0.40
P13	– 0.34

Development of new forecast models for seasonal rainfall over three broad homogeneous regions of India

Just as there are demands for forecasts of rainfall on shorter time scales like a month, users also want to have forecasts over small regions like meteorological sub-divisions and districts. It is equally difficult to build models for this purpose using statistical techniques. However, since 1999, IMD has been issuing long-range forecasts for three broad homogeneous regions of India, viz. northwest India, northeast India and the peninsula (Figure 5). This is possible by choosing regions in which the rainfall variation in each of the meteorological sub-divisions comprising the region is positively and significantly correlated with the

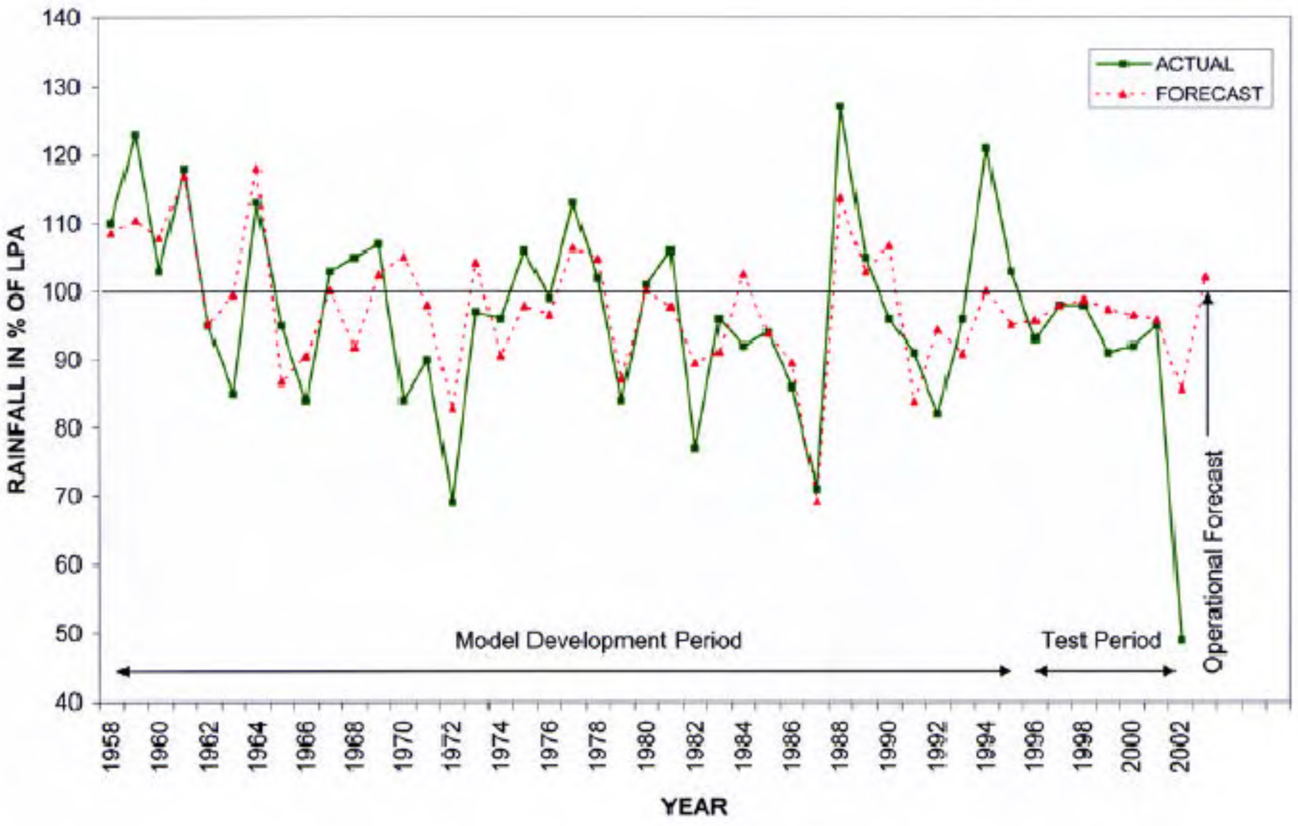

Figure 4. Performance of the power regression model for July rainfall. Actual (forecast) in percentage of LPA is shown in green (red).

area-weighted rainfall variation over the region as a whole. The standard deviation of seasonal rainfall over NW India, NE India and the peninsula is 19, 7 and 13% respectively. IMD has been generating such forecasts with three individual power-regression models based on different sets of predictors. This year, we have further refined these models by examining the stability of the parameters, removing the unstable ones and adding some new predictors. The predictors for the three new power-regression models for the three homogeneous regions are given in Table 7 and their model errors are within ± 8%.

Operational long-range forecasts issued by IMD in April and July 2003 and their verification

On the basis of the various models described above, IMD issued its operational long-range forecasts for the 2003 monsoon season in two stages; first on 16 April using data available up to March end and then on 9 July 2003 using data up to June end. Full details of these forecasts can be seen on the IMD website www.imd.ernet.in. Details of the forecasts and their verifications are given in Table 8.

All the models developed by IMD for long-range forecast of the southwest monsoon rainfall and adopted for operational purposes in 2003, have thus stood the test of verification in real time. The monsoon rainfall actually realized in 2003 has been close to the forecast figures. The updated probabilities indicated by the 10-parameter probabilistic model have given a realistic picture.

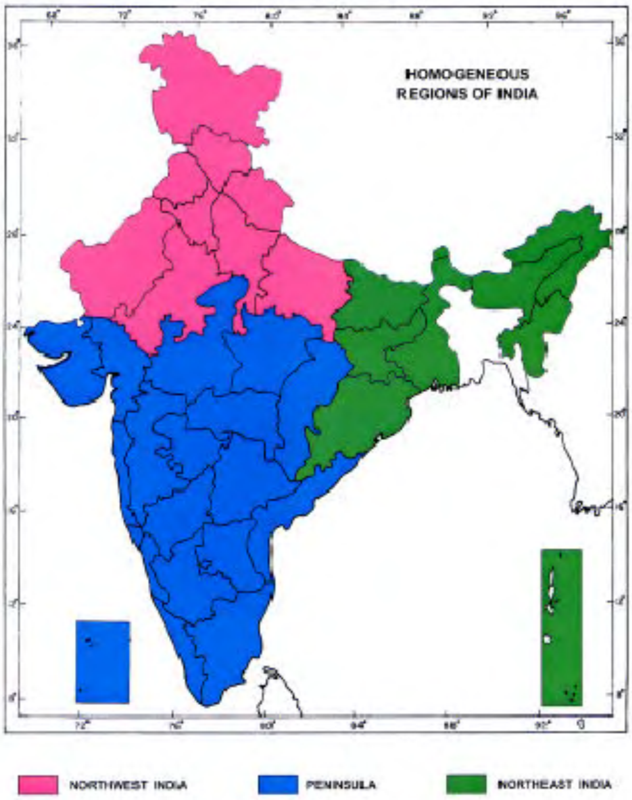

Figure 5. Geographical area of the three homogeneous regions of India.

Conclusion and future directions

In this article, we have discussed the details of new statistical models developed and adopted by IMD for long-range forecasts of southwest monsoon rainfall. All these new models proved to be accurate in 2003 in an operational mode and have helped restore the credibility of IMD's forecasts following the drought of 2002. From the year 2003, IMD has gone a considerable way ahead towards meeting some longstanding requirements of different users. It is now in a position to provide a suite of forecasts, including an early forecast in April, an update in July, 5-category probabilistic forecasts, a forecast for July rains and forecasts for three broad homogeneous regions of the country.

We have brought out the necessity of subjecting statistical forecast models for monsoon to constant scrutiny. The temporal instability of some predictors does not allow the continued use of such models over a long period of time without change. This throws a challenge to the modeller as good parameters are hard to find. It also creates a dilemma for the operational forecaster who would like to have a time-tested model which he can trust rather than one which is being frequently updated.

The periodic revision of regression models has also to be viewed in the light of the possible impact of global warming and climate change on the inter-annual variability of the Indian summer monsoon rainfall[24,25]. The likely influence of processes like ENSO and the North Atlantic Oscillation should be examined in greater detail.

It is an accepted fact that long-range forecasts with a higher resolution in time and space scales can only be generated by dynamical models which can handle far better, the complex regional-scale interactions and manifestations of regional rainfall variability. IMD has already initiated the implementation of a dynamical seasonal prediction system. However, dynamical models do not yet have sufficiently high skill to accurately simulate the salient features of the mean monsoon and its variability[26–29]. It has been found that the simulation of the Indian mon-

Table 7. Predictors for three broad homogenous regions

Parameter (defined in Table 1)		
NW India	NE India	Peninsula
P12	P11	P9
P6	P10	P11
P9	P2	P1
P2	P12	P6
P11	P7	P4
P10	P6	P2
P8	–	P10

Table 8. IMD's operational long-range forecasts for 2003 and their verification

Region	Issued on	Period	Forecast	Actual
For the country as a whole	16 April 2003	June–September	Quantitative: 96% of LPA ± 5% Probability: Drought: 21% Below Normal: 39% Near Normal : 14% Above Normal: 23% Excess : 3%	
	9 July 2003	June–September	Quantitative: 98% of LPA ± 4% Probability: Drought: 6% Below Normal: 28% Near Normal : 43% Above Normal: 17% Excess : 6%	102% of LPA
For the country as a whole	9 July 2003	July	102% of LPA ± 9%	107% of LPA
NW India	9 July 2003	June–September	97% of LPA ± 8%	108% of LPA
NE India			99% of LPA ± 8%	102% of LPA
Peninsula			100% of LPA ± 8%	99% of LPA

soon circulation and rainfall features with coupled ocean–atmosphere models[30] is also difficult. Super-ensemble-type dynamical model predictions[31] are found to improve the skill in prediction of monsoon rainfall.

Dynamical models are likely to go through several years of development efforts before they can completely replace statistical models. Work on the refinement of statistical models has therefore to continue. There are some statistical models which use only SST data[32], since the oceans play an important role in modulating the monsoon rainfall through atmospheric tele-connections. Many recent studies[18,33–35] have brought out the strong influence that the Indian Ocean is seen to exert on the southwest monsoon rainfall. We have to encourage Indian efforts towards the development of reliable ocean models, particularly for the Indian Ocean[36] that would ultimately help in climate prediction. On the observational front, long and accurate time series of weekly SSTs are required over the Indian Ocean. For our better understanding of monsoon processes, special experimental initiatives like BOBMEX[37] and ARMEX[38] need to be encouraged.

While IMD has been successful in making a model for the forecasting of July rainfall, this has not been possible for other monsoon months. However, some recent studies[39,40] have reported results on the prediction of the active-break cycles of the monsoon. On a spatial scale, we have to explore possibilities of demarcating more than the present three homogeneous regions of the country using better criteria.

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Responses of *Brugia malayi* – Indian leaf monkey (*Presbytis entellus*), a non-human primate model of filariasis, to diethylcarbamazine, ivermectin and CDRI compound 82-437

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We have earlier developed the Indian leaf monkey (*Presbytis entellus*) – *Brugia malayi* model of human filariasis that develops the characteristic filarial disease manifestations such as episodic febrile attacks and limb oedema. We report here the responses of the model to known antifilarials, diethylcarbamazine (DEC) and ivermectin (IVM) and a new antifilarial CDRI compound 82-437. DEC treatment at 18 and 200 mg/kg × 5 days induced respectively, 53.4 and 86.1% reduction in microfilaraemia by day-8 post-treatment (p.t.). Microfilaraemia further decreased by 90–99% between day 14 and day 63 p.t. IVM (1.5 mg/kg × 5 days) induced 45 and 90% fall in microfilaraemia by day 7 and day 21 p.t. respectively. Compound 82-437-treated animals showed gradual decrease in microfilaraemia after day 7 p.t., with more than 95% suppression on the day of autopsy. Untreated infected monkeys showed characteristic increases in microfilaraemia till day 63 p.t. In both DEC and compound 82-437-treated animals, microfilaraemia was associated with changes in eosinophil count and immune responses. The adult worm recovery from lymph nodes/lymphatics was 0, 4.6, 1.1, and 5.3% in DEC-, IVM- and compound 82-437-treated and untreated monkeys, respectively. Compound 82-437-treated monkeys showed enlarged popliteal and inguinal lymph nodes with a few intact worms and granulomas. No lesions were detected in the nodes of DEC-treated monkeys. Nodes in untreated controls showed granulomas, follicular atrophy, sinus histiocytosis, and intact or phagocytosed mf in sinuses. Adult worms were found in the afferent lymphatics with or without associated lymphangitis.

It is concluded that the Indian leaf monkey – *B. malayi* model responds to antifilarial treatment in a predictable manner, with the parasitological profile and changes in absolute eosinophil count (AEC), immunological and histological parameters largely resembling those of human subjects.

THE sub-periodic strain of *Brugia malayi* has been found to be easily transmittable to the Indian leaf monkey (*Presbytis entellus*). The model also mimics some of the characteristics of human filarial manifestations such as fever, episodic attacks of limb oedema[1,2], persistent limb oedema or scrotal swelling and other pathophysiological responses[3,4]. However, the utility of such a non-human primate model for tertiary screening of potential filaricides depends on the similarity of the host–parasite relationship and its response to known filaricides. The present study was therefore undertaken to evaluate the chemotherapeutic response of known antifilarials, diethylcarbamazine (DEC), ivermectin (IVM), standard drugs for filariasis, and compound 82-437, an orally active adulticidal antifilarial developed at the Central Drug Research Institute (CDRI), in *B. malayi* – rodent model[5]. Further, since the efficacy of antifilarials like DEC and IVM has been linked to their ability to alter the immune responses of the host[6–8], certain immunological parameters such as circulating immune complexes, filaria-specific IgG, lymphocyte proliferative responses to filarial antigen and mitogen were also investigated along with the assessment of changes in the lymph nodes and other lymphoid organs following treatment with DEC, IVM and CDRI compound 82-437. The present article reports the results of such a study.

Materials and methods

Animals

Young adult male Indian leaf monkeys, commonly known in Hindi as langur, of 3–4 kg body weight were obtained from local suppliers. The animals were immediately kept in quarantine for 45 days during which they were subjected to routine health-check procedures, including clinical biochemistry and hematology and were thoroughly examined for tuberculosis (TB; using Mantoux test and chest X-ray), intestinal helminthiasis (examination of faeces), and microfilariae (by night-blood examination). Animals found positive for intestinal helminths were treated with mebendazole (Zodex, Concept Pharmaceuticals, Mumbai, India) at 20 mg/kg, p.o. for 3 days, which was repeated after three weeks. None of the monkeys was positive for filaria. On completion of the quarantine and health-check, the animals were transferred to animal quar-

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