Prediction of Indian summer monsoon: Status, problems and prospects

M. Rajeevan

India Meteorological Department, Pune 411 005, India

In this article, we review the present status and problems and future prospects of long-range forecasts of Indian summer monsoon. Since 1988, the India Meteorological Department has been issuing forecasts based on 16-parameter power regression and parametric models. All these forecasts are proved to be reasonably correct. However, in some years, forecast error was larger than the model error of ± 4%. In 2000, four new promising predictors were introduced in the operational models. Using an empirical model with 100 years of data (1901–2000), we show that Indian summer monsoon predictability exhibits epochal variations. During the recent years the model is showing poor forecast skill due to weakened coupling between the boundary forcing and Indian monsoon. In spite of serious efforts by the modelling groups, there are still problems in the dynamical predictions of Indian monsoon. Prediction of Indian monsoon variability is found to be sensitive to the initial conditions, suggesting that chaotic internal dynamics may ultimately limit the predictability of Indian summer monsoon.

IN an agricultural country like India, the success or failure of the crops and water scarcity in any year is always viewed with the greatest concern. These problems are closely linked with the behaviour of the summer monsoon rains in India. Mean monsoon rainfall over India as a whole during June–September is 88 cm with a coefficient of variation of 10%. There are known vagaries of the monsoon as regards the time of onset as also of the nature and amount of monsoon rains and its distribution in different parts of the country. Indian summer monsoon rainfall (ISMR) exhibits large inter-annual variations (Figure 1). These vagaries generate profound socio-economic impact on many spheres of national activities. Thus long-range prediction (seasonal prediction) of summer monsoon rains becomes very crucial and useful.

The India Meteorological Department has been issuing forecasts of summer monsoon rains for over hundred years. In fact, India was the first country in the world to start operational seasonal prediction. The first forecast was issued on 4 June 1886 based on the inverse relationship between the Himalayan snow cover and ISMR. In early 1900s Gilbert Walker made significant contributions[1] to the long-range forecasting system in India. He introduced the concept of correlation and regression approach in long-range forecasting.

In this article we review the present status, problems and future prospects of long-range forecasting system of ISMR. Several authors[2–4] have discussed the history and status of IMD's long-range forecasting system.

Basic premise and methods of seasonal prediction

The predictability of day-to-day weather patterns in the tropics is restricted to 2–3 days. However the seasonal mean monsoon circulation in the tropics is potentially more predictable. This is because the low-frequency component of the tropical variability is primarily forced by slowly varying boundary forcing, which evolves on a slower time scale than that of the weather systems themselves[5]. These boundary conditions include sea surface temperature (SST), land surface temperature, soil moisture, snow cover, etc. Observational studies have established that the ISMR is linked with several surface boundary conditions like east Pacific SST[6], Indian Ocean SST[7], land surface temperature[8], Eurasian and Himalayan snow cover[9]. However studies based on data analysis[10] and numerical models[11], have suggested that mean monsoon circulation may not be entirely forced by boundary conditions but is also governed by internal dynamics to some extent, which ultimately limits the predictability of ISMR. This aspect will be discussed further later. Thus there is a limit in predictability of seasonal monsoon rainfall over India.

There are two main approaches in seasonal prediction of monsoon rainfall: (i) comprehensive diagnostic and empirical studies of climate and circulation anomalies combined with statistical analysis and (ii) dynamical prediction using atmospheric general circulation models. IMD has been using the first method (statistical approach) successfully for monsoon seasonal prediction for many decades.

Present setup of long-range prediction system in India

From 1924 to 1987, forecasts were issued for NW India and peninsular India using separate multiple

---

*For correspondence. (e-mail: rajeevanm@hotmail.com)

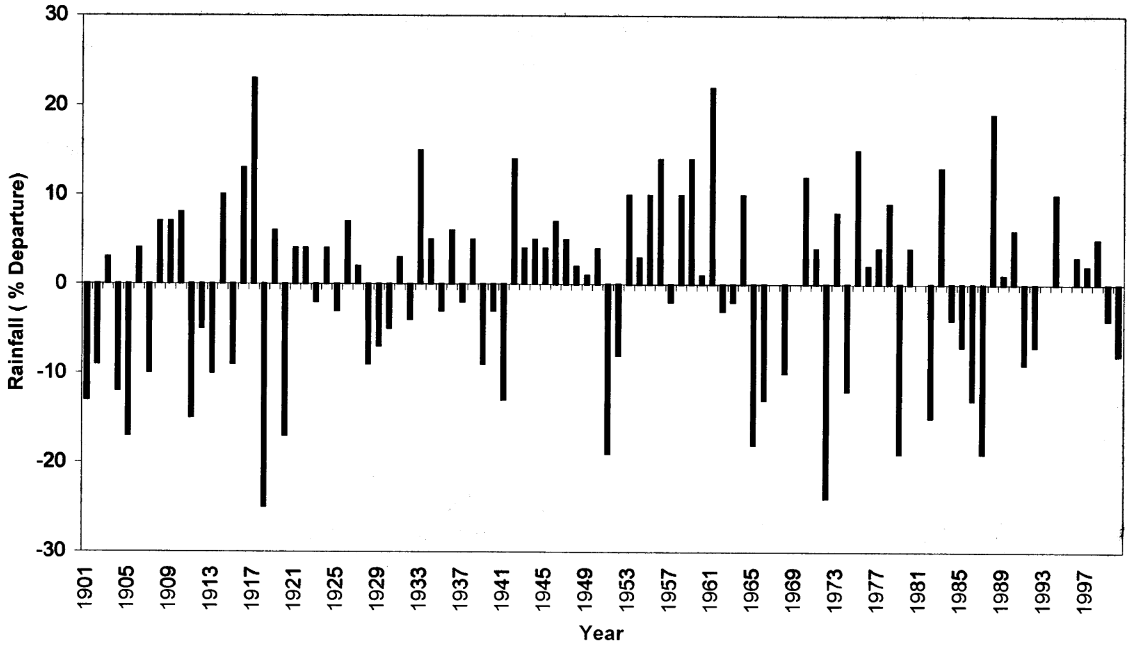

Figure 1. Time series of Indian summer monsoon rinfall (ISMR) as percentage departures. Period: 1901–2000.

regression models. These models were updated as and when required. Verification of these forecasts (1924–1987) revealed that about 64% of these forecasts were proved correct.

During the decade of 1981–90, concerted efforts made to develop new LRF techniques resulted in the development of new types of LRF models, namely dynamical stochastic transfer, parametric and power regression models. Since 1988, the long-range forecasts are issued for the country as a whole based on the 16-parameter parametric and power regression models[12,13]. The parametric model is purely qualitative and it indicates whether monsoon would be wet (normal or excess) or deficient. In this model, equal weight is given to each of the 16 parameters. The power regression model is a quantitative model, which acknowledges the nonlinear interactions of different important climatic forcings with the Indian monsoon.

In 2000, four predictors whose relationship with ISMR has weakened were replaced from the 16-parameter model. The four predictors removed from the model are April 500 hPa ridge position, north India temperature (March), 10 hPa zonal wind and spring Darwin pressure. This revised model was used in 2000 for the operational long-range forecast of monsoon rainfall over the country as a whole. The revised list of 16 parameters is given in Table 1. The new four predictors used in the revised model are (i) Arabian Sea SST (November to January), (ii) South Indian Ocean SST (February + March), (iii) Europe pressure gradient (January) and (iv) Darwin MSL pressure tendency (April–January). Correlation coefficients for the period 1958–1999 of these predictors with ISMR are 0.44, 0.49, – 0.34 and – 0.55 respectively. Arabian Sea SST and South Indian Ocean SST are two newly identified[7] parameters which are positively correlated with ISMR. The parameter Europe pressure gradient indicates the strength of westerly zonal flow over the mid-latitudes in winter.

Table 1. List of 16 parameters

Parameter
El Nino (same year) (Nino 1 + 2)
El Nino (previous year) (Nino 1 + 2)
South Indian Ocean SST (Feb. + March)
East Coast India temperature (March)
Arabian Sea SST (Nov. + Dec. + Jan.)
Central India temperature (May)
N H Temperature (Jan. + Feb.)
Darwin pressure tendency (April–Jan)
N H Pressure (Jan. to April)
Southern Oscillation Index (Mar to May)
Indian Ocean Equatorial Pressure (Jan to May)
Europe Pressure Gradient (January)
Argentina pressure (April)
50 hPa East–West Ridge Extension (Jan. + Feb.)
Himalayan Snow Cover (Jan. to Mar.)
Eurasian Snow Cover (Dec.)

The verification of IMD's operational forecasts from 1988 to 2000 is shown in Figure 2. It can be seen that since 1989, ISMR has been normal (± 10%) as correctly predicted by IMD. In 1997, when there were apprehensions regarding the prospects of ISMR due to El Nino, the IMD's prediction was ultimately proved correct. However, forecast errors in some years (1994, 1997 and 1999) were more than the model error of (± 4%. The root mean square error of the forecasts for the period 1988 to 2000 was 7.6%.

IMD also operates other models like multiple regression (MR), dynamic stochastic transfer (DST) and power transfer for preparing the long-range forecasts. Recently models based on the principal component regression (PCR) and neural network technique were also developed[14,15]. Forecasts based on these models are also included in the forecast memorandum being issued by the IMD every year. However, the IMD's official forecast is based only on the 16-parameter parametric and power regression models.

In view of great demand from many users, in 1999, IMD reintroduced the forecasts for three homogenous regions of India (NW India, NE India and peninsula). For these forecasts, separate forecast models based on power regression, MR, DST, PCR and neural network techniques have been indigenously developed. The verification of these forecasts for 1999 and 2000 is given in Table 2.

Changing predictability of Indian monsoon

The statistical models are based on the assumption that the association measured by the correlation coefficient (CC) between the predictor and the predictant, computed based on past data would persist in future also. However, secular variations between the predictors and ISMR have been noted[3,16,17]. These variations have been found to be linked to changes in the global and regional circulation patterns. These secular changes therefore pose serious challenge to long-range forecasting. Analysis of more than 20 known predictors has revealed that many of the predictors have lost the significant relationship with ISMR during the recent years (not shown).

Epochal changes in Indian monsoon predictability for the last 100 years have been examined using a statistical model developed with 100 years of data (1901–2000). Five predictors (NW India minimum temperature in May, N H temperature (Jan. + Feb.), Argentina Pressure (spring), Darwin pressure tendency and Nino 3 SST index tendency (MAM–DJF) for the period 1901–2000 have been used to develop a statistical model. These predictors represent the ENSO forcing, land surface conditions over Eurasia and the intensity of the heat low over NW India. The principal component analysis (PCA) of these five predictors was made and the resultant three significant principal components were further used to develop a multiple regression model. The results are shown in Figure 3, which shows the 11-year moving correlation between (i) the first principal component and ISMR, (ii) the actual and hindcast ISMR or skill of the model. The 11-year running mean of standard deviation anomaly (subtracted from long term mean of 10%) of ISMR also is shown.

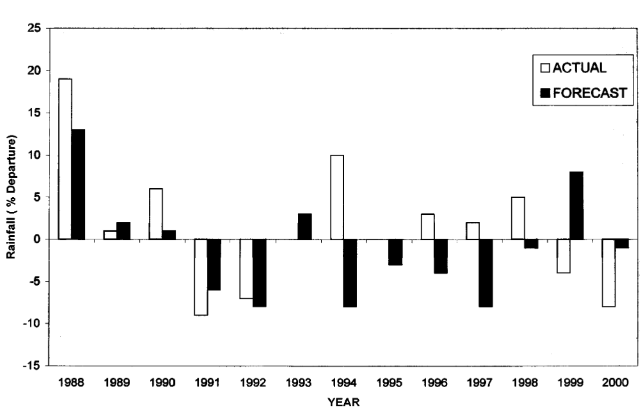

Figure 2. Actual (white) and operational forecasts (black) of ISMR (as percentage departures). Period: 1988–2000.

The CC between the first principal component and ISMR reflects the general relationship between the predictors and ISMR. This relationship was weak in 1930s and 1940s and during the recent years. During the 1960s to 1990s this relationship was, however, very strong. Obviously, the skill of the model also shows similar type of variations. The model skill was positive during 1960s to 1990s. However, the model skill was negative during 1930s and 1940s and also during the recent years. It is also interesting to note that the standard deviation of ISMR was found to be smaller (or ISMR remains within normal limits) during 1930s and 1940s and again during the recent years. It is to be mentioned that ISMR was normal successively for the last 12 years since 1989. Therefore periods of normal monsoon rainfall coincide with those of weaker relationship between the predictors and ISMR and negative model skill. This is curious because it is generally believed that statistical models do not show good skill when the inter-annual variation of monsoon is very large. However, here we have seen that good positive model skill was observed when the inter-annual variability of ISMR was also very large. This is because the predictor–ISMR relationship was stronger during the periods with large inter-annual variability. Thus, stronger boundary forcing–ISMR coupling leads to large inter-annual variations of ISMR. When this coupling becomes weak, monsoon tends to remain normal as observed in the recent years. But during these periods empirical models based on these boundary forcing parameters will show poor predictive skill.

Table 2. Verification of operational forecasts for the homogeneous regions of India 1999–2000

Year	Region	Forecast (%)	Actual (%)
1999	NW India	111	94
	Peninsula	114	90
	NE India	98	89
2000	NW India	102	94
	Peninsula	98	89
	NE India	100	97

Dynamical prediction

In the mid-eighties, modelling groups initiated systematic efforts for the simulation of the monsoon circulation using dynamical models. Under the Monsoon Numerical Experimentation Group (MONEG) program, a series of monsoon simulations were carried out by a number of general circulation modelling groups around the world to simulate the 1987 and 1988 monsoons using identical boundary forcings and initial conditions. The results showed that there were significant differences in simulating the mean monsoon by different models. Most models had systematic errors in simulating the regional features of the monsoon. However, a majority of the models could simulate the correct tendency of the inter-annual variability between 1987 and 1988 (ref. 18). These results also showed that a large fraction of the simulated Indian monsoon was forced by the SST variations over the Pacific.

As a second part, the Atmospheric Inter-comparison Project (AMIP) was initiated[19]. It provided a unique opportunity to study the potential predictability of inter-annual fluctuations of the atmosphere based on ensembles of multi-annual integrations of atmospheric general circulation models (AGCM)[20]. In this project, many of the world's AGCMs have been integrated over the 10-year period 1979–1988 with identical specified SSTs. In addition, multiple realizations of the 10-year period have been obtained by running some of the models from different initial conditions (but with the same SSTs). As an AMIP diagnostic subproject, Gadgil and Sajani[21] have validated the monsoon precipitation over Africa and India in AMIP runs of 30 AGCMs. Their study revealed that (i) some models simulate the observed seasonal migration of the primary rainbelt over the Asian West Pacific region, in several other models, this rainbelt remains over the equatorial oceans in all the seasons, (ii) very few models are able to capture all the fluctuations between good and poor monsoon seasons observed in the AMIP decade and (iii) a good rainfall climatology and proper simulation of the inter-annual variation are associated. Sperber and Palmer[20] showed that the simulation of the inter-annual variability of monsoon rainfall differs widely from one model to another, indicating the great sensitivity of this region on resolutions and physical parameterizations of the models.

European Centre for Medium Range Weather Forecasting (ECMWF) co-ordinated a European collaborative Project called PRediction Of climate Variations On Seasonal to inter-annual Time scales (PROVOST)[22]. Under this project, a series of ensemble runs using T63L19 ECMWF model were made for each season. For monsoon season there were nine ensemble members corresponding to nine different initial conditions starting from 23 May. The integrations were carried out using the observed SST during the 15-year period of 1979–1993. Figure 4 shows the ensemble mean model precipitation during the period

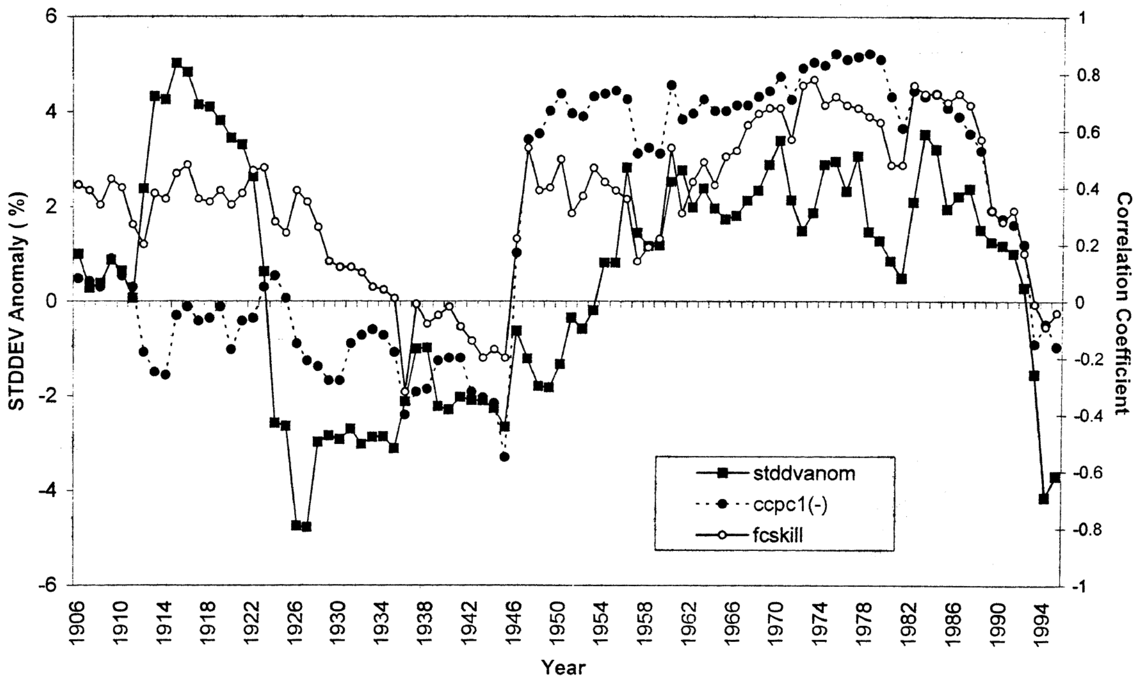

Figure 3. Epochal variations of Indian monsoon predictability for the period 1901–2000. 11-year moving correlation coefficient between the first principal component and ISMR (dotted line with filled circles). 11-year moving correlation coefficient between actual and hindcast ISMR (forecast skill) (continuous line with open circle). 11-year moving anomaly (subtracted from the long term mean of 10%) of standard deviation of ISMR. (Continuous line with filled squares).

June–September, averaged over the period 1979–1993. The observed precipitation (ECMWF reanalysis) for the same period is also shown. It can be seen that the spatial pattern of precipitation over north Bay of Bengal simulated by the model was close to the observed pattern. But model precipitation over SH (corresponding to the southern hemisphere Equatorial Trough) and NE India is higher than that observed by 6 mm/day. On the other hand, the model could not simulate the precipitation pattern over the west coast of India as observed. There, the model precipitation was smaller than that observed by 6 mm/day.

The inter-annual variability of Indian summer monsoon rainfall (averaged over land regions between 7.5°N to 30°N, 70°E to 95°E) during the period 1979 1993, for the nine ensembles along with the IMD's observed rainfall anomalies are shown in Figure 5. The mean of the

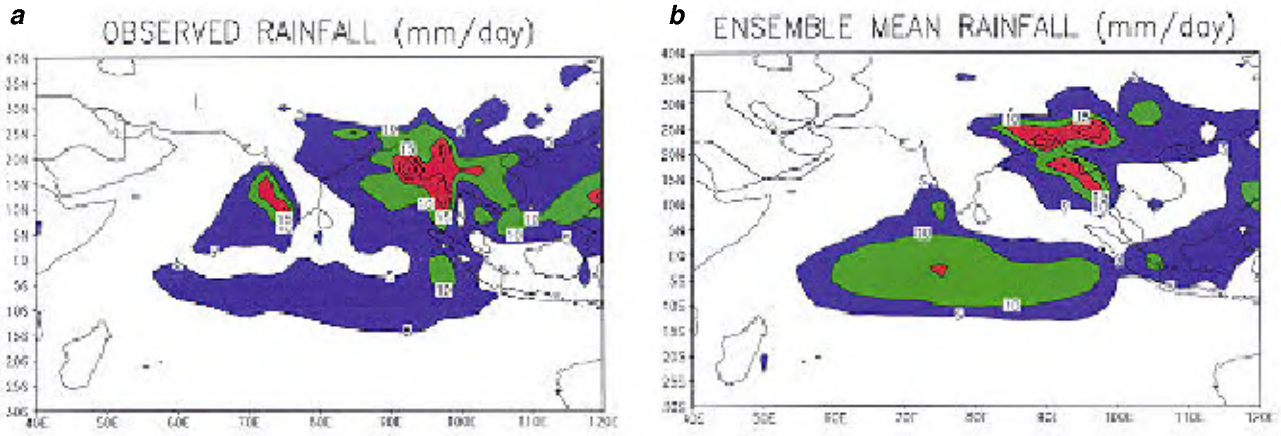

Figure 4. Comparison of PROVOST prediction of monsoon (June–September) rainfall. Observed (ECMWF reanalysis) (***a***) and PROVOST ensemble mean (***b***) Contour interval: 5 mm/day.

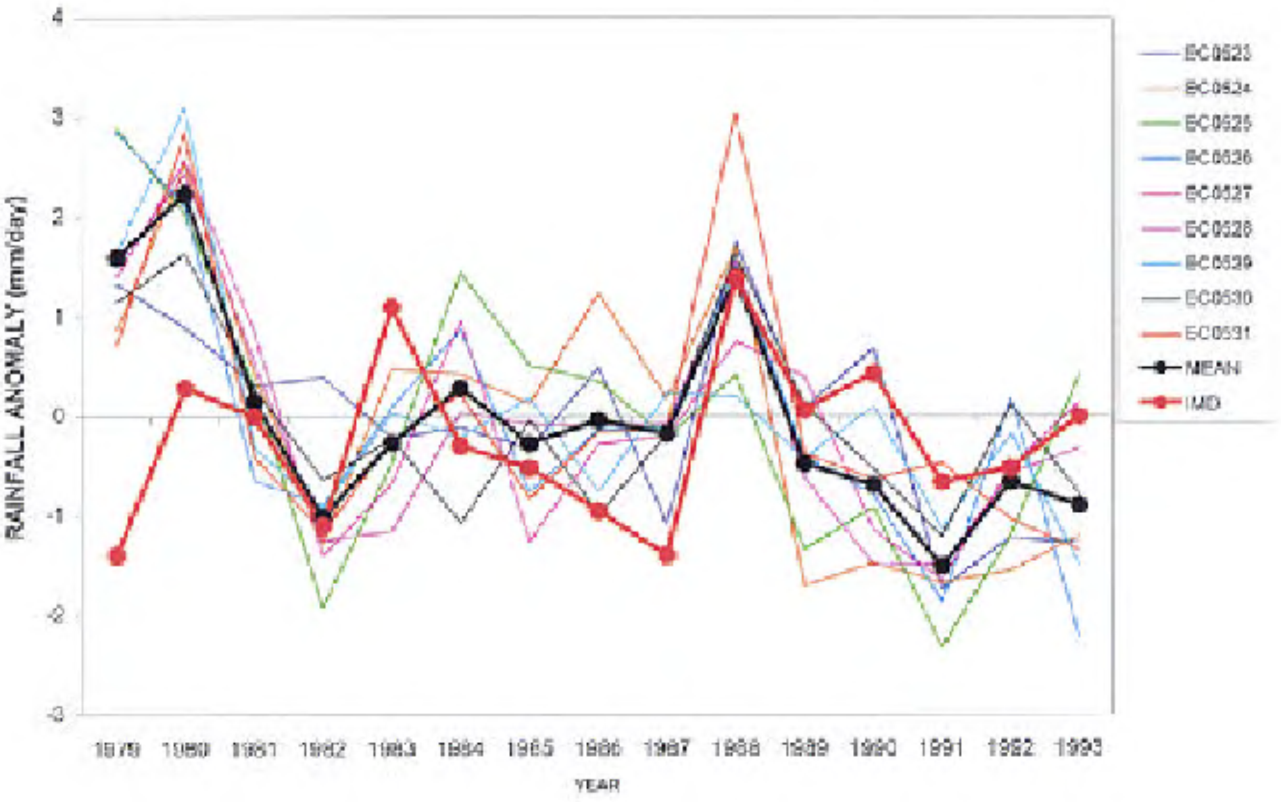

Figure 5. PROVOST ensemble predictions of ISMR anomaly (mm/day) for the period 1979–1993. Individual ensemble member predictions are shown as thin coloured lines. The ensemble mean is shown as thick continous line in black. The observed (IMD) ISMR anomalies are shown as thick continous line in red.

Table 3. Correlation coefficient between the model precipitation and observed precipitation for the PROVOST ensemble members (Period: 1979–1993)

Ensemble member	CC	Ensemble member	CC
ECM0523	0.29	ECM0528	0.10
ECM0524	0.20	ECM0529	0.09
ECM0525	– 0.01	ECM0530	0.33
ECM0526	0.06	ECM0531	0.42
ECM0527	0.18	Mean	0.21

ensembles is shown as thick line. The model rainfall anomaly in 1981, 1982, 1985, 1988 and 1992 is very well close to the observed rainfall anomaly. But in some other years (1979, 1980, 1987 and 1990) the model rainfall anomaly is very much different from the observed. For 1979, the model predicted excess rainfall, while the observed rainfall anomaly was largely negative. The correlation between the model monsoon precipitation and observed precipitation for the nine ensemble members is shown in Table 3. Except for the ensembles 8 and 9, all other correlations are poor and statistically insignificant. Further, there is also a large spread among the correlation coefficients.

From Figure 5, it can be further inferred that there is a large dispersion among the ensemble members in individual years. This dispersion is quite comparable to the inter-annual fluctuations. Thus, the simulation of the seasonal mean Indian monsoon rainfall is found to be sensitive to small changes in the initial conditions. However the prediction of the seasonal mean rainfall in other parts of the tropics (Sahel, NE Brazil, equatorial Pacific) does not seem to be sensitive to small changes in the initial conditions[11,23]. This indicates that the mean monsoon circulations may not be entirely forced by slowly varying boundary conditions, but is also governed by an intrinsically unpredictable component (internal dynamics) associated with the initial conditions[11,24]. This may be due to the possibility that some dynamic processes in the monsoon area are intrinsically chaotic. One candidate is the intra-seasonal variability associated with the migration or oscillation of convective zones associated with active and break periods of the monsoon[11]. From a physical point of view, the possibility of chaotic fluctuations between the break and active monsoon phases suggests a dynamic tension between these two states corresponding to two quasi-equilibrium positions of the tropical convergence zone. Small imbalances in simulating this dynamical tension can lead to significant systematic error[11]. The frequency of chaotic intra-seasonal fluctuations can determine the seasonal mean monsoon and limits the predictability[10]. For example, the above normal performance of monsoon in 1997 (a major ENSO year) is attributed to the intra-seasonal fluctuations[25].

Concluding remarks

About 80% of the variability of ISMR can be predicted using empirical models from information available in preceding winter and spring. However, statistical models have the problems of secular variation of the relationship with the predictors as observed during the recent years. Therefore constant updating of the models and objective review of the predictors are very much essential. Also, our understanding of the recent epochal changes in circulation patterns and their link with the monsoon variability needs to be improved. Since the boundary forcing–ISMR coupling is showing a weakening during the recent years, empirical probability forecasts can be tried in conjunction with the forecasts now being prepared using other statistical models.

For a better dynamical simulation of mean monsoon and its inter-annual variability, dynamical models must simulate the seasonal variation of the precipitation zones and the spatial pattern of the intra-seasonal oscillations more realistically. The sensitivity of monsoon simulations on initial conditions warrant ensemble prediction techniques using operational dynamical models. From these ensemble simulations, probability forecasts can be prepared[26]. Further, multi-model super-ensemble forecasts can be also more effective[27].

1. Walker, G. T., *Mem. India Met. Dept.*, 1923, **24**, 75–131.
2. Jaganathan, P., Report, India Met. Dept., 1960, pp. 67.
3. Thapliyal, V. and Kulshrestha, S. M., *Mausam*, 1992, **43**, 239–248.
4. Thalpiyal, V., *J. Arid Environ.*, 1997, **36**, 385–403.
5. Charney, J. G. and Shukla, J., in *Monsoon Dynamics* (ed. Lighthill, J.), Cambridge University Press, Cambridge, 1981, 99–110.
6. Rasmusson, E. M. and Carpenter, T. H., *Monthly Wea. Rev.*, 1983, **111**, 354–384.
7. Rajeevan, M., Pai, D. S. and Thapliyal, V., *Mausam*, 2001 (in press).
8. Rajeevan, M., Pai, D. S. and Thapliyal, V., *Met. Atmos. Phys.*, 1998, **66**, 157–171.
9. Bamzai, A. S. and Shukla, J., *J. Climate*, 1999, **12**, 3117–3132.

10. Ajaymohan, R. S. and Goswami, B. N., *Curr. Sci.*, 2000, **79**, 1106–1111.
11. Webster, P. J., Magana, V. O., Palmer, T. N., Shukla, J., Tomas, R. A., Yanai, M. and Yasunari, T., *J. Geophys. Res.*, 1998, **103**, C7, 14451–14510.
12. Gowariker, V., Thapliyal, V., Sarkar, R. P., Mandal, G. S. and Sikka, D. R., *Mausam*, 1989, **40**, 115–122.
13. Gowariker, V., Thapliyal, V., Kulshrestha, S. M., Mandal, G. S., Sen Roy, N. and Sikka, D. R., *Mausam*, 1991, **42**,125–130.
14. Guhathakurta, P., Rajeevan, M. and Thapliyal, V., *Met. Atmos. Phys.*, 1999, **71**, 255–266.
15. Rajeevan, M., Guhathakurta, P. and Thapliyal, V., *Met. Atmos. Phys.*, 2000, **73**, 211–225.
16. Parthasarathy, B., Rupa Kumar, K. and Munot, A. A., *J. Climate.*, 1991, **4**, 927–938.
17. Hastenrath, S. and Greisher, L., *Proc. Indian Acad. Sci.*, 1993, **102**, 35–47.
18. Palmer, T. N., Brankovic, C., Viterbo, P. and Miller, M. J., *J. Climate*, 1992, **5**, 399–417.
19. Gates, W. L., *Bull. Am. Meteorol. Soc.*, 1992, **73**, 1962–1970.
20. Sperber, K. R. and Palmer, T. N., *J. Climate*, 1996, **9**, 2727–2750.
21. Gadgil, S., Sajani, S. and AMIP Modelling Groups, WCRP-100, 1998, WMO/TD-No. 837.
22. Brankovic, C. and Palmer, T. N., *Monthly Wea. Rev.*, 1997, **125**, 859–874.
23. Shukla, J., *Science*, 1998, **282**, 728–731.
24. Krishnamurthy, V. and Shukla, J., COLA Technical Report No. 81, 2000, COLA, Maryland, USA, pp. 39.
25. Shen, X. and Kimoto, M., *J. Meteorol. Soc. Jpn.*, 1999, **77**, 1023–1037.
26. Mo, R. and Straus, D. M., COLA Technical Report No. 74, 1999, COLA, Maryland, USA, pp. 33.
27. Krishnamurti, T. N. *et al.*, *Science*, 1999, **285**, 1548–1550.

ACKNOWLEDGEMENTS. I thank DGM, IMD for giving permission to participate in the micro-symposium organized by the Indian Academy of Sciences at Goa and deliver the talk. I also thank Dr U. S. De and Dr V. Thapliyal for their encouragement and providing the facilities to carry out this study. Dr C. Brankovic, ECMWF had supplied me the PROVOST simulations for which I am thankful to him.

Estimating nuclear waste production in India

M. V. Ramana[†], **Dennis George Thomas**[‡] **and Susy Varughese**[‡,*]

[†]Center for Energy and Environmental Studies, Princeton University, Princeton, NJ 08544, USA
[‡]Department of Chemical Engineering, Indian Institute of Technology, Chennai 600 036, India

We estimate the amount of nuclear waste generated by different steps in the fuel cycle followed in the Indian nuclear programme, based on standard methodologies and public sources of information. The basic input in the case of power reactors is the amount of electricity they have produced. For research reactors, the inputs are their rated capacities and an average capacity factor. While our waste estimates are based on assumptions and the limited amount of public data available, it would be easy to modify the estimates, should new information become available.

NUCLEAR waste has been a contentious aspect of nuclear power programmes around the world[1]. The Nuclear Energy Agency, Organization for Economic Cooperation and Development (OECD), observes: 'One of the key issues that has dominated the nuclear debate in recent years has been the safe management of radioactive wastes . . . radioactive wastes have caused more public concern than any other type of waste'[2]. In India too, apprehensions have been expressed about this segment of the nuclear programme[3]. Any examination of this subject, however, must begin with the actual amount of nuclear waste produced. Since this figure does not seem to be available publicly, in this paper we estimate the amount of nuclear waste produced by the Indian nuclear programme. The basic data that we use to perform this estimate are the amounts of electricity produced by the various power reactors, and the nominal power rating and an assumed capacity factor for the research reactors, *CIRUS* and *Dhruva*. Using standard figures and methodologies, we estimate waste production from different steps in the nuclear fuel cycle.

The nuclear fuel cycle in India begins with the mining and milling of uranium and the processing of the mined uranium into U_3O_8. This is followed by fuel fabrication and use in research and power reactors. The resulting spent fuel is then reprocessed to recover uranium and plutonium[4]. At each stage of this cycle, different kinds of nuclear waste are produced.

The management of nuclear waste depends upon its radioactive and other physical and chemical properties. In order to evolve guidelines for such management, it is customary to classify nuclear waste into different categories. India classifies its wastes into Low-Level Waste (LLW), Intermediate-Level Waste (ILW) and High-Level Waste (HLW). The category, potentially active waste (PAW) is also used[5] (Table 1).

In some cases, these individual categories are further divided according to radioactivity levels for operational purposes. For example, low-level solid waste is placed in four categories (Category I–IV) based on the surface beta and gamma dose and alpha activity[6] (Table 2).

To calculate the amount of waste produced, we start with an estimate of the amount of fuel irradiated. The primary sources of irradiated fuel are the ten power reactors (two Boiling Water Reactors (BWR) at Tarapur and eight Pressurized Heavy Water Reactors (PHWR); we do not include the four PHWRs that have recently been commissioned) and the two research reactors, CIRUS and Dhruva. We estimate the amount of fuel irradiated based on figures published by the Nuclear Power Corporation of India, for the amount of electricity generated in the case of power reactors. Since CIRUS and Dhruva do not produce any electricity, we assume a capacity factor of 60% to make our estimates. There are other smaller research reactors, in particular the Fast Breeder Test Reactor (FBTR), but we will neglect their contribution. This is because these are relatively low in power and so do not produce too much waste and because there is no adequate basis (such as electricity generated) to calculate the amount of waste generated. In the case of the FBTR, electricity production would not be a good indicator of the amount of waste generated, since as a test reactor it was used to experiment with different kinds of fuel and so on. For power reactors, we use the formula:

Table 1. Categorization of wastes in India

Category	Activity level A (Ci/m^3)	Remark
PAW	$< 10^{-6}$	Potentially active
LLW 1	$10^{-6} < A < 10^{-3}$	
LLW 2	$10^{-3} < A < 10^{-1}$	May require shielding
ILW	$10^{-1} < A < 10^{4}$	Shielding necessary
HLW	$> 10^{4}$	Shielding and cooling necessary

Source: Rodriguez[5].

Table 2. Radioactive low level solid waste categories

Waste category	Surface dose rate (mGy/h)
I	< 2
II	2–20
III A	20–500
III B	> 500

Source: Guha[6].

---

*For correspondence. (e-mail: susy@iitm.ac.in)