International Journal of Water Resources and Environmental Engineering Vol. 4(11), pp. 322-326, November 2012
Available online at http://www.academicjournals.org/IJWREE
DOI: 10.5897/IJWREE11.097
ISSN 2141-6613 ©2012 Academic Journals

Full Length Research Paper

Development of monsoon model for long range forecast rainfall explored for Anand (Gujarat-India)

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Accepted 29 March, 2012

Rainfall plays an important role in agricultural production. It has a profound influence on the growth, development and yields of a crop, incidence of pests and diseases, water needs and fertilizer requirements in terms of differences in nutrient mobilization due to water stresses and timeliness and effectiveness of prophylactic and cultural operations on crops. Occurrences of erratic rainfall are beyond human control. However, it is possible to adapt to or mitigate the adverse effects if a forecast of the rainfall can be had in time. Accurate information on rainfall is essential for the planning and management of agricultural operations. Nevertheless, rainfall is one of the most complex and difficult elements of the hydrology cycle to understand and to model due to the complexity of the atmospheric processes that generate rainfall and the tremendous range of variation over a wide range of scales both in space and time. Thus, accurate rainfall forecasting is one of the greatest challenges in operational hydrology. An attempt has been made here to develop a Final Long range Forecast of seasonal monsoon based on multiple regression technique to predict monsoon rainfall based on 16 parameters related with Anand (Gujarat). The 16 parameter of Anand for the last 25 years (1980-2005) was used for development of model. The operational forecast was given by using mean of both the models which has less error, (Avg. Error 3.5% for MRM-I and 5.1% for MRM-II respectively). The operational forecast is having still less error i.e. 0.6% for all data (1980-2009) and 2.9% for independent data (2006 to 2009), so it can be used for giving final forecast.

Key words: Rainfall forecast, multiple regression techniques, rainfall analysis.

INTRODUCTION

Agriculture is largely weather and climate sensitive. Nearly 70% of total cultivated land in India depends on rainfall for assured crop yield. As far as agricultural planning is concerned, the importance of weather forecasting needs no over emphasis.

The ever growing demands of, not only short or medium range, but also long range forecasts, has placed greater burden and responsibilities on the national weather services. If monsoon rainfall receives less than normal and its distribution is not proper, yields are drastically reduced in proportion to the deficient rainfall that Location (Willmot, 1982). Therefore, forecasting of monsoon rainfall is highly essential for long range location wise in India as whole. The India Meteorological Department (IMD) has been issuing long-range forecasts of the southwest monsoon rainfall since 1886 (Gowariker et.al., 1991).

It was, however, the extensive and pioneering work of Gilbert Walker, 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 (Walker, 1924). Since then, IMD's operational long-range forecasting system has undergone changes in its approach and scope from time to time (Rajeevan et al., 2004).

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MATERIALS AND METHODS

The weekly weather data of Tmax, Tmin, RH-II, WS, BSS and rainfall

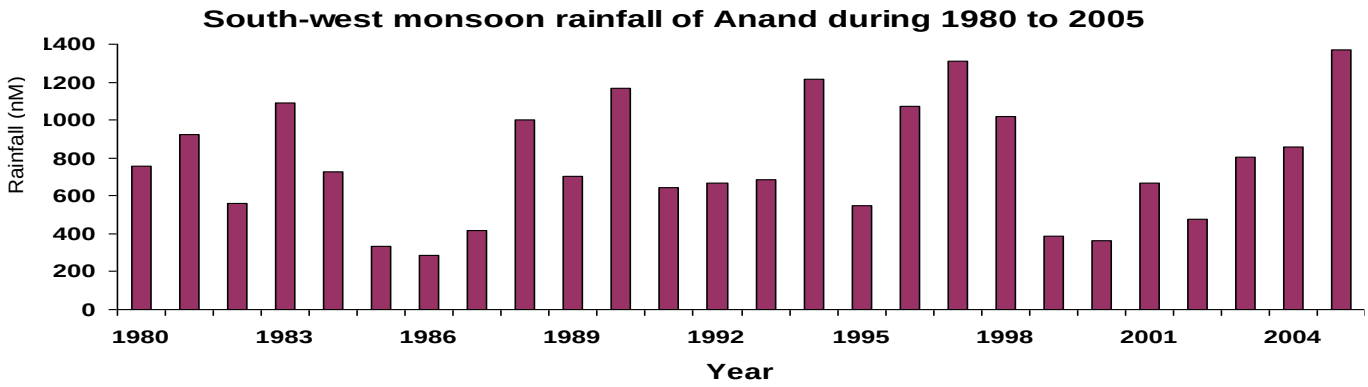

Figure 1. SW monsoon (23-39 mw) rainfall of Anand (Gujarat-India).

of 25 years of the station is considered for development of Regression model. The forecast is given from data of five selected predictor parameters viz. Tmax, Tmin, RH-II, BSS and Wind Speed is used for model. The weather data from 4th March to 21st May (10 to 20 mw) is considered for Multiple Regression Analysis. These five parameters were taken for March, April and May (1-21st May) months as parameters for predicting Monsoon season rainfall (June-Sept.) of Anand. This period coincided with warming of the sea water which is the main cause for formation of water vapour and thereby formation of clouds. The movement of wind enables the movement of clouds. The period between 15th March and 10th April is the period of formation and development of warm pool over south- west Arabian Sea. The multiple regression models was developed by using predictor data of 1980 to 2005 and model was tested for independent data for four years of 2006 to 2009. The validation for rainfall forecast for the year 2006, 2007, 2008 and 2009 was done with actual rainfall recorded at Anand station. The LPA of monsoon rainfall for Anand was 771.1 mm from 1980 to 2005.

RESULTS AND DISCUSSION

Multiple regression model (MRM-I) for predicting rainfall for Anand (Preliminary forecast)

It could be found from the Figure 1 monsoon rainfall (1980-2005) that the rainfall ranged between 285.0 mm (1986) and 1371.0 mm (2005). This shows that there are lots of variations in receipt of monsoon rainfall at Anand (Gujarat).

The model was developed by using weather data of 25 years (1980-2005) and tested for independently data of 4 years 2006 to 2009. The Predictors are Maximum Temperature (Tmax), Minimum Temperature (Tmin), Relative Humidity (Afternoon- RH-II), Wind Speed (WS) and Bright Sun Shine Hour (BSS) and used for the month of March, April and May months (up to 22nd May).

The multiple Regression model (Equation) for long-range Monsoon rainfall prediction for Anand is developed and given as below. The predicted and actual rainfall is depicted in Figures 2 and 3 as bar graph and line diagram respectively. The coefficient of determination ($R^{2)}$ was found to be 0.85 which is also quite accurate.

Y= (-12405.43) + (-204.19*MAR Tmax) + 377.06*MAR Tmin + (-20.63*MAR RH-2) + 719.58*MARBSS + (-403.62*MAR WS) + 286.14*APR Tmax + (-399.88*APR Tmin) + 101.23*APR RH-2 + (-358.75*APR BSS) + 191.63*APR WS+143.13*MAY Tmax + 71.59*MAY Tmin + (-14.5.*MAY RH-2) + (-65.98*MAY BSS) + 87.82*MAY WS

Error analysis

The error analysis was carried out by using statistical techniques as explained by Wilmot (1982) for testing of model. The Mean Bias Error (MBE), Mean Absolute Error (MAE), Root Mean Square Error (RMSE), Percent Error (PE) and Average Error was found out for all data (1980-2009) and for independent data (2006-2009) separately and given in Tables 1 and Table 2. The average error of model for all data is only 3.2% and for independent data it was only 5.3% (Table 1), which is quite lower which indicate better accuracy in model prediction.

Multiple regression model (MRM-II) for predicting rainfall for Anand (Final forecast)

The second model was developed for prediction of SW monsoon rainfall of Anand by considering parameters from the month of November to March. This model gives prediction on 2nd April, so planners and other end users like farmers, agro-meteorologists can get sufficient time for use of this prediction. The parameters were finalized to 16 based on study of correlation between parameters and south west monsoon rainfall along with various combinations and predictors are Relative humidity (Afternoon) and Wind Speed for the month November, Maximum Temperature, Bright Sun Shine Hour, Wind Speed for the month December, Maximum Temperature,

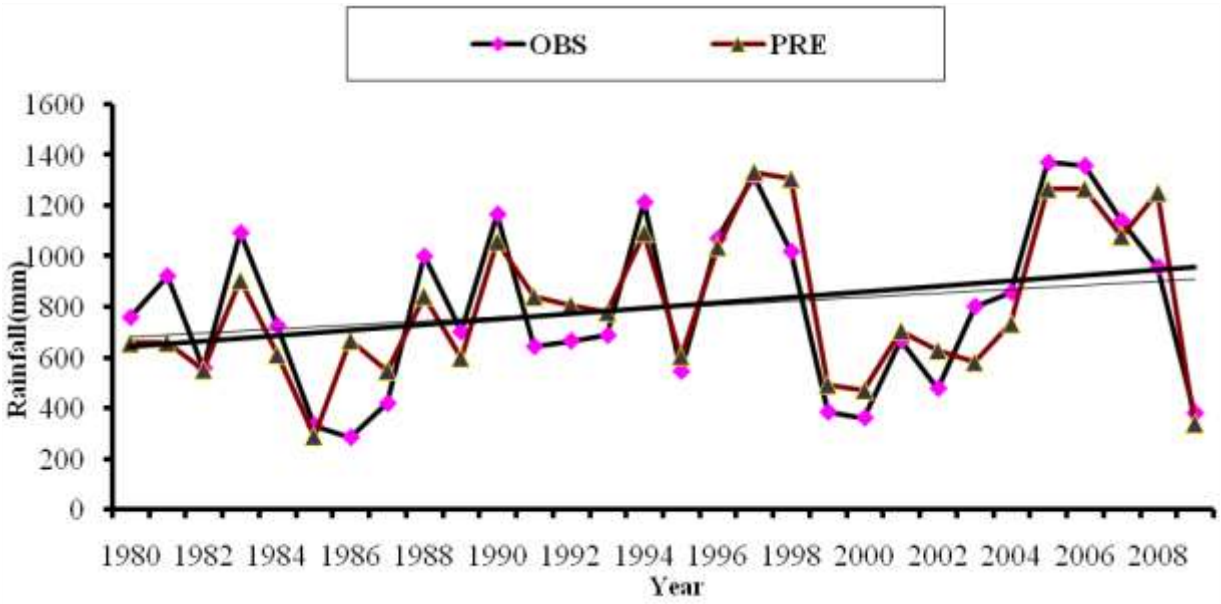

Figure 2. Observed and predicted SW monsoon rainfall (MRM-I) at Anand for the year 1980-2009.

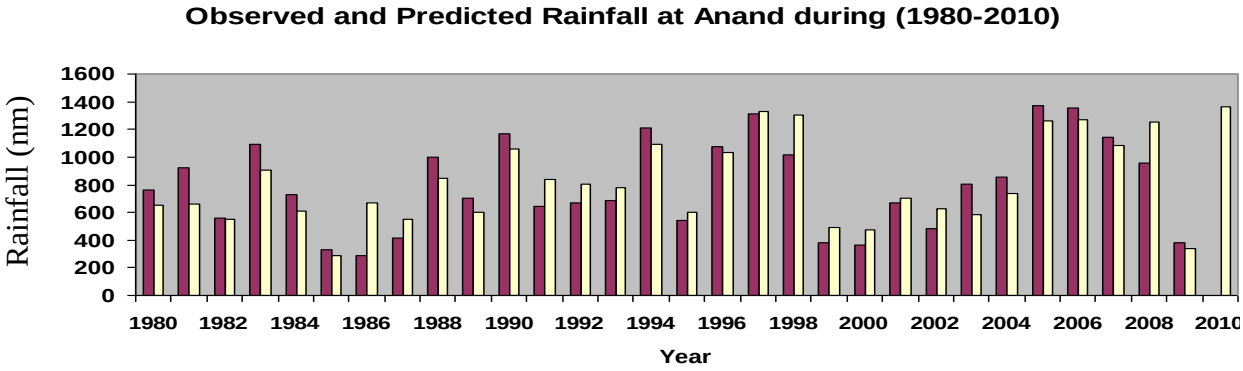

Figure 3. Observed and predicted SW monsoon rainfall at Anand (MRM-II) for the year 1980-2010.

Table 1. Error analysis of model (MRM-I).

Error analysis	All data (1980 to 2009)	Outside data (2006 to 2009)
Mean ABS error (mm)	109.3	177.1
Mean bias error (mm)	-20	-16.1
RMSE (mm)	144	192.9
PE (%)	18.1	24.2

Relative humidity (Afternoon), Minimum Temperature for the month January, Maximum Temperature, Relative humidity (Afternoon), Bright Sun Shine Hour, Wind Speed, Minimum Temperature for the month February, Maximum Temperature, Bright Sun Shine Hour, Minimum Temperature for the month of March. The predicted and actual rainfall is depicted in Figures 4 as bar graph and line diagram respectively. The coefficient of determination (R^2) was found to be 0.74 which is indicating accurate prediction.

Y = 691.78+28.32*NOV RH2 + (-143.2*NOV WS) + (-266.77*DEC MAXT) + (-178.917*DEC BSS) + (-155.792*DEC WS) + 77.877*JAN MAXT + 170.08*JAN

Table 2. Validation of MRM-I for the year 2006-2010 with actual rainfall with % of deviation.

S/no.	Year	Observed rainfall (mm)	Predicted rainfall (mm)	Difference	% Deviation from actual
1	2006	1358.2	1050.7	307.5	-22.6
2	2007	1140.7	1004.9	135.8	-11.9
3	2008	957.4	804.5	152.9	-15.9
4	2009	380.9	492.9	112.0	29.4
5	2010	922.3	1363.0	440.7	-32.33

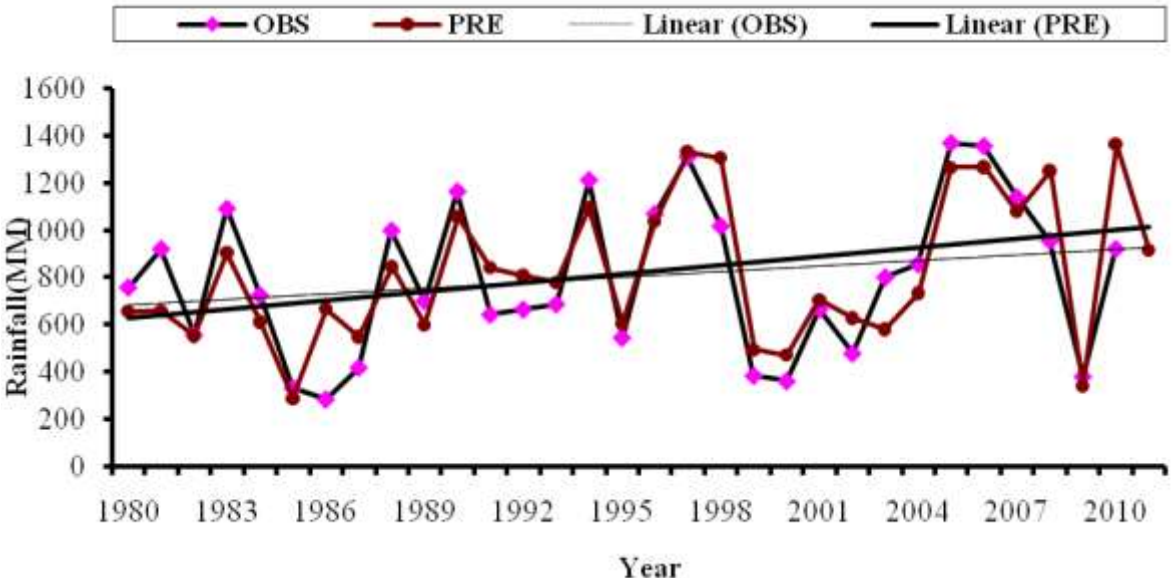

Figure 4. Observed and predicted SW monsoon rainfall at Anand (MRM-II) for the year 1980-2010.

Table 3. Error analysis of second model (MRM-II).

Error analysis	All data (1980 to 2009)	Outside data (2006 to 2009)
Mean ABS error (mm)	4.1	122.4
Mean BIAS error (mm)	5.9	3.3
RMSE (mm)	156.3	192.9
PE (%)	19.63	16.5

MINT + (-31.35 *JAN RH2 + 153.29*FEB MAXT + (-202.40*FEB MINT) + 41.030*FEB RH2 + (-205.95 *FEB BSS) + 126.95*FEB WS + (-102.92*MAR MAXT) + 313.11*MAR MINT + 309.4334*MAR BSS.

Error analysis

The error analysis was carried out by using statistical techniques as explained by Wilmot (1982) for testing of model. The Mean Bias Error (MBE), Mean Absolute Error (MAE), Root Mean Square Error (RMSE), Percent Error (PE) and Average Error was found out for all data (1980-2009) and for independent data (2006-2009) separately and given in Tables 3. The average error of model for all data is only 5.1% and for independent data it was only 1.9% (Table 4), which is quite lower which indicate better accuracy in model prediction (Varshneya and Karande 1998).

Conclusion

The rainfall forecasting was generated by multiple regression analysis techniques. The rainfall data of previous years were analyzed and the rainfall forecast which has been generated by MRM-I and MRM-II is matching to the actual rainfall. The average error is of

Table 4. Validation of MRM-II for the year 2006-2010 and forecast for 2011 of Anand (LPA=771.1 mm).

S/n	Year	Observed rainfall (mm)	Predicted rainfall (mm)	Difference (mm)	% Deviation from observed
1	2006	1358.2	1266.6	91.6	-6.74
2	2007	1140.7	1079.5	61.2	-5.36
3	2008	957.4	1251.6	294.2	+30.72
4	2009	380.9	338.4	42.5	-11.15
5	2010	922.3	1294.0	371.7	-28.72
6.	2011	-	1102.0	330.90 (LPA 771.1 mm)	+42.90

5.1% for all data (1980-2009) and 1.2% for independent data (2006-2009). Hence, the predicted rainfall of 2011 for Anand by MRM-II is 1102.00mm for S-W monsoon (June-September), which is above the normal (LPA 771.10 mm).

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