LONG RANGE FORECAST OF SINDH MONSOON

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Abstarct:

In this study effort has been made to examine the relationship of Sindh monsoon rainfall with some of the important global and regional parameters. The Sindh Monsoon Rainfall Indices (SMRI) were examined with the monthly mean values of SST (Sea Surface Temperature), IHP (Indian Ocean High Pressure), SOI (Southern Oscillation Index), NHT (Northern Hemisphere Temperature), Pakistan's regional data. It has been found that the SMRI is significantly correlated with SOI, IHP, Mean temperature of Balochistan and Mean Temperature of Punjab . Multiple regression equation has been developed using these predictors based on thirty nine years (1957 to 1995) of monthly values. The equation then applied on the period 1996-2003 for verifying the results.

Introduction:

Pakistan comprises of four provinces, namely, Punjab, North West Frontier, Balochistan and Sindh. The Province of Sindh lies in the lower Indus basin. River Indus is the most important river of the province. The classical name of the river was Sindhu (meaning an ocean) from where the Sindh province derives its name.

The neighbouring regions of Sindh are Balochistan to the west and northwest, Punjab in the north and the vast Thar Desert of Sindh, Punjab and Indian Rajasthan to the east. To the south are the Arabian Sea and the Rann of Kutch. The Province of Sindh lies between 23 -35 degrees and 28-30, north latitude and 66-42 and 71-1 degrees east longitude. It is about 579 kms in length from north to south and on the average about 281 kms in breadth from east to west, at a few places the breadth is nearly 442 kms. It covers 140,915 square kms.

The Sindh province is mainly a plain land and stretches between the Punjab plain and the Arabian Sea. The plain comprises a vast fertile tract stretching westward from the narrow strip of flood plain on the right bank of River Indus, and a vast expanse of desert stretching eastward from the left bank. The desert area is dry and desolate like Cholistan in the Punjab plain. But, the plain area right of River Indus is green, full of plants and vegetation.

However, its southern part is one of the worst areas of Pakistan for water logging and salinity. There are many lakes in Sindh. Manchhar and the Kinjhar Lakes act as great water reservoir for feeding canals in the adjacent areas.

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The climate of Sindh is hot and dry yet great variability in temperature and rainfall is experienced. The average temperature of the summer months (MJJA) is 33.2 degrees Celsius and those of winter months (DJF) 17.5 degree Celsius. Figure-1 illustrates the normal maximum and minimum temperatures of Sindh. In the northern part of Sindh the extreme temperatures occur in summer. Jacobabad recorded 52.5 degrees Celsius in June 2nd 2003.

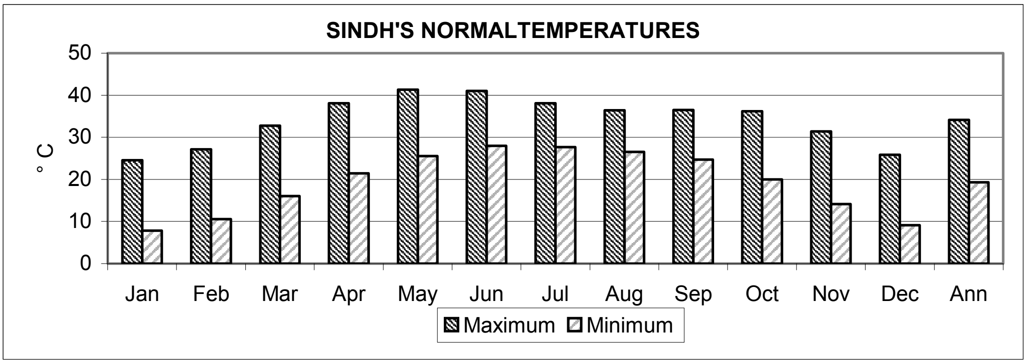

Figure 1: Sindh's Normal (1961-90) Maximum and Minimum temperatures

Hot winds, called "loo", blow across the plains during the day, dust storms and thunderstorms occasionally lower the temperature. The diurnal variation in temperature may be as much as 10.5 to 17.0 °C. Winters are cold with minimum temperature of about 6°C in January. The climate along the coast is modified by sea breezes.

Rainfall is meager, annual total is only 160 mm. Figure-2,3 shows annual & monsoon (JAS) normal rainfall isohyetal maps. Very small amount of rain falls in winter (13 mm normal) while the chief amount of rain falls in summer. The normal (1961-90) rain fall in monsoon season is 125 mm and is highly variable (SD 85 mm). The rainfall over Sindh is a result of monsoon depressions forming in the Bay of Bengal and occasionally moving westward into lower Sindh. Sometimes upper air vortex or trough intensifies over North Arabian Sea and moves inland giving heavy shower and storm surge. Such weather situations become disastrous and cause heavy loss of lives and properties.

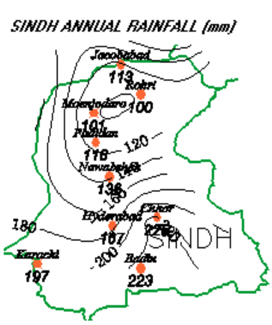

Figure 2: Sindh Normal Annual Rainfall

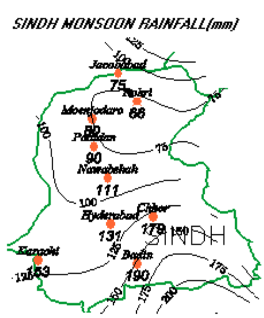

Figure 3: Sindh Normal Monsoon Rainfall

The intra - seasonal variability is high over Balochistan and Sindh. This intra - seasonal variability is due to snow cover over hills, soil moisture and varying sea-surface temperature. (Shukla, 1987). The intra - seasonal variability in summer rainfall (JAS) sometimes leads to droughts and floods over different parts of Pakistan. The result is reduced agricultural production affecting the national and regional economy.

In view of the agricultural output and industrial production both being affected by the intra-seasonal variability of the summer (JAS) monsoon rainfall, the prediction of summer monsoon rainfall is very essential for planning and policy making.

In the present study an attempt has been made to develop a prediction model of summer monsoon rainfall over the Sindh province of Pakistan. In this context the interaction of ocean-atmosphere coupled phenomena like:

- Sea Surface Temperature (SST), Nino 1+2
- Sea Surface Temperature (SST) ,Nino 4
- Southern Oscillation Index (SOI)
- Indian Ocean High Pressure (IHP)
- Northern Hemisphere Temperature (NHT)

As well as number of local meteorological parameters have also been considered.

Review:

Gilbert Walker (1910, 1923) developed an objective procedure for long-range forecast of monsoon precipitation over India. Walker (1924) also attempted long range forecast for sub regions of India (pre independence) by dividing the country into three regions: Peninsula, North-east India, and North-west India. Regression formulas were developed separately for these three regions.

The regression equation for Northwest India developed by Walker was modified by Pakistan Meteorological Department during 1948-1951 for the whole of Pakistan. The new regression equation was developed for predicting summer rainfall (JAS) for Pakistan and this method has been in operational use since then. So far the prediction results of this model have been satisfactory under normal prevailing conditions. However sometimes the result has been poor due to abnormal weather conditions, local topographic effects, (Zeya and Khan ,1991).

No serious attempts however appeared to be made to modify the operational prediction formula for summer rainfall for quite a long time. Later Chaudhary (1992) developed a regression formula using six predictors for summer monsoon rainfall over Pakistan as well as for the following two provinces of Pakistan.

i. North West Frontier Province summer monsoon rainfall
ii. Punjab- summer monsoon rainfall

For the other two provinces Chaudhary (1992) also identified the following potential predictors:

- Temperature of a number of cities in Pakistan as well as Northern hemisphere and El-Nino
- Surface level pressure field over Pakistan and Southern Oscillation Index.

- 500 hPa ridge position at 75°E in April,
- 10 hPa zonal pattern in January
- Eurasian snow cover of December

In this paper identification of predictors and development of prediction equation for Sindh summer monsoon rainfall has been undertaken. Later on prediction equation for other provinces will be developed.

Data:

Sea Surface Temperature (SST):

The SST data consist of monthly mean temperature value for grid points in each 5 degree latitude and 5 degree longitude area with large regions Nino 1+2 (0-10S)(90W-80W) & Nino 4 (5N-5S) (160E-150W) for the period 1957 to 2003.

Southern Oscillation Index (SOI):

The SOI is the monthly value (anomaly) of the difference in mean sea level pressure (MSL) between Tahiti (18°S, 15°W) and Darwin (12°S, 131°E).

This index was recommended for the inter annual climate variability by Chen (1982). The period of the data used is 1957 to 2003.

Indian Ocean High Pressure (IHP)

Seasonal (Winter, Spring, Summer and Autumn) values of Indian Ocean High Pressure, in mbs for the period of 1957 to 2000 were used.

Northen Hemisphere Temperature (NHT)

The monthly mean temperature values (in °C) of Northern Hemisphere have been taken for the period 1957 to 2000.

Rainfall Data

The rainfall data used in this study consist of monthly total rainfall values (in mm) of the following eight stations of Sindh for the year 1957 to 2003.

i. Badin
ii. Chhor
iii. Hyderabad
iv. Jacobabad
v. Karachi
vi. Nawabshah
vii. Padidan
viii. Rohri

The data for first 39 years (i.e. 1957 to 1995) were used to develop regression equation and later eight years (i.e. 1996 to 2003) data were used to verify the equation. The data were obtained from the Computerized Data Processing Centre (CDPC) of Pakistan Meteorological Department (PMD). Rainfall variation of selected stations over the months of the normal period (1961-90) is shown in Figure-4 .

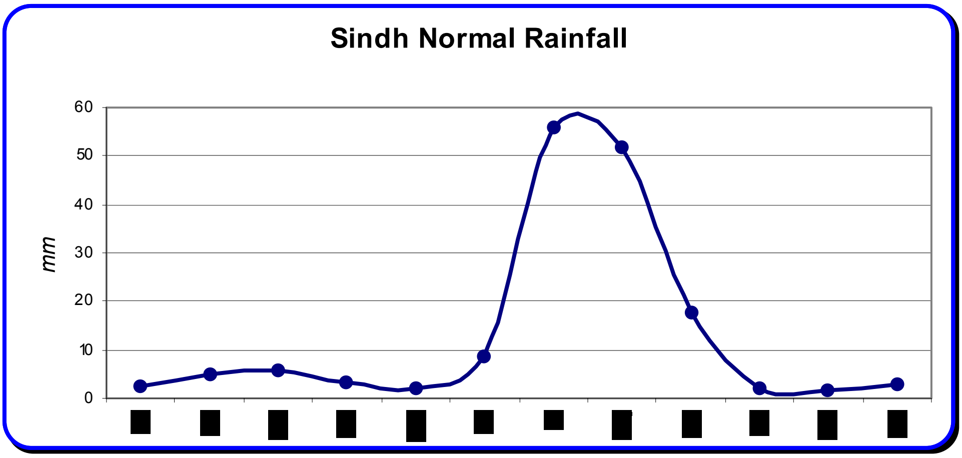

Figure 4: Sindh Normal (1961-90) Rianfall

Mean Temperature of Punjab:

Mean monthly temperature (in degree C) of the following nine stations of Punjab province for the period 1957 to 2003 was taken.

i. Bahawalpur
ii. Faisalabad
iii. Islamabad
iv. Jehlum
v. Khanpur
vi. Lahore(Airport)
vii. Lahore (Observatory)
viii. Multan
ix. Sialkot

Mean Station Level Pressure of Punjab:

Average of mean monthly station level pressure at 0300 UTC and 1200 UTC (in hPa) of the above nine stations of Punjab province for the period 1957 to 2003 was taken.

Mean Temperature of Balochistan:

Mean monthly temperature (in degree C) of the following eight stations of Balochistan province for the period 1960 to 1998 was taken.

i. Dalbandin
ii. Jiwani
iii. Nokkundi
iv. Panjgur
v. Pasni
vi. Quetta
vii. Sibi
viii. Zhob

Mean Station Level Pressure of Balochistan:

Average of mean monthly station level pressure at 0300 UTC and 1200 UTC (in hPa) of all above eight stations of Balochistan province for the period 1957 to 2003 was taken.

Methodology:

Most of the studies in long range forecasting are based on the statistical and empirical techniques. Pakistan is divided by four regions, Sindh, Balochistan, Punjab and North West Frontier Province (NWFP). The northern parts (NWFP and Punjab) received more rainfall than southern parts (Sindh and Balochistan) during monsoon season (JAS).

Rainfall indices were developed for each year by using following formula over the period July 1957 to September 1995 (Figure-5).

$$I_j = \frac{1}{N}\sum_{i=1}^{N}\left(\frac{R_{ij} - \overline{R_i}}{\sigma_i}\right)$$

Where:

I_j = Rainfall Index for year j
R_{ij} = Amount of the rainfall in the season at station i in the year j
R_i = Average rainfall for all the years considered at station i.
σ_i = Standard Deviation of rainfall at station i.
N = Number of stations.

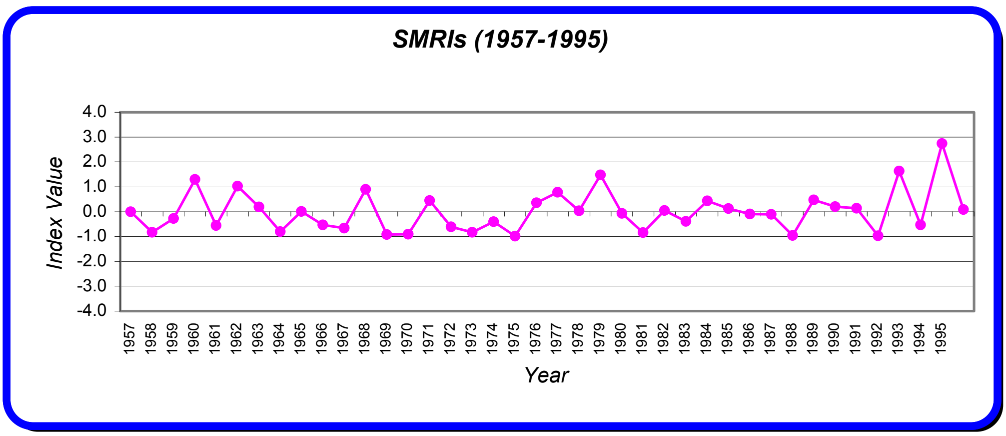

Figure 5: Sindh Monsoon Rainfall Index

Following nine parameters were selected for the period June 1956 to June 1995 for the examination of significant correlation coefficient at 95 % significance level.

i. Sea Surface temperature , Nino 1+2 (SSTa)
ii. Sea Surface temperature, Nino 4 (SSTb)
iii. Southern Oscillation Index (SOI)
iv. Indian Ocean High Pressure (IHP)
v. Northern Hemisphere Temperature (NHT)
vi. Mean monthly pressure of Balochistan (BLC-PP)
vii. Mean monthly temperature of Balochistan (BLC-T)
viii. Mean monthly pressure of Punjab (PNJ-T)
ix. Mean monthly temperature of Punjab (PNJ-P)

The monthly SMRIs for the period July 1957 to September 1995 were correlated with the above mentioned nine predictors for the period July 1956 to June 1995. It was observed that out of these nine predictors only following seven predictors have significant correlation coefficient (Table-1)

Table 1: **Significant Correlation Co-efficient with t and p values**

Variable	Month	r(X,Y)	t	p
NHT	January	0.37	2.41	0.02
SOI	October	-0.37	-2.44	0.02
IHP	Spring	0.36	2.35	0.03
BLC-TEMP	September	0.39	2.56	0.02
BLC-TEMP	December	0.33	2.14	0.04
PNJ-TEMP	July	-0.35	-2.23	0.03
PNJ-TEMP	June	-0.33	-2.12	0.04

These seven predictors were retained for developing the required regression equation(s).

i. NHT, predicted year's January month (NHT_01)
ii. SOI, previous year's October month (SOI_10)
iii. IHP, current year's Spring season (IHP_spr)
iv. Mean Temperature of Balochistan, previous year's September month (BLC_09T)
v. Mean Temperature of Balochistan, previous year's December month (BLC_12T)
vi. Mean Temperature of Punjab, previous year's July (PNJ_07T)
vii. Mean Temperature of Punjab, predicted year's June (PNJ_06T)

In this study all calculations are based on the normalized value of rainfall of the selected stations. For the predictors the anomalies based on (1957-1995) were calculated.

Result:

The statistical package "STATISTICA version 5.0" was used for computing the significant correlation (Table-2) values and developing the Multiple Regression equation. Following Multiple Regression equation was developed using the forward Stepwise method.

Table 2: **Dependent and Independent variables**

VARIABLES			
1: SMRI	Dependent	2: NHT_01	Independents
		3: SOI_10	
		4: IHP_SPR	
		5: BLC09T	
		6: BLC12T	
		7: PNJ07T	
		8: PNJ06T	

Table 3: **Regression Summary for Dependent Variable: SMRI (1957-1995)**

Method=Forward Stepwise						
STAT. MULTIPLE REGRESS.	Regression Summary for Dependent Variable: SMRI (1957-1995)					
	R= .61392576 R2= .37690484 Adjusted R2= .32349669					
	F(3,35)=7.0571 p<.00078 Std.Error of estimate: .69017					
N=39	**BETA**	**St. Err. of BETA**	**B**	**St. Err. of B**	**t(35)**	**p-level**
Intercpt			7.007	4.619	1.517	0.138
BLC09T Y1	0.342	0.134	0.115	0.045	2.541	0.016
SOI_10 Y2	-0.382	0.134	-0.031	0.011	-2.860	0.007
PNJ06T Y3	-0.309	0.135	-0.294	0.128	-2.297	0.028

Multiple Regression Equation

$$SMRI = y1*0.115 - y2*0.031 - y3*0.294 + 7.007$$

Verification:

The above Regression Equation, generated with stepwise forward method, was used to predict SMRIs for the period 1996-2003. The actual and predicted SMRIs values are shown in Table-4. The graph showing the actual and computed SMRIs is given in Figure-6.

Table 4: **Observed and forecast values**

Year	Observed	Predicted
1996 (SMRI58-96)	-0.80	0.86
1997 (SMRI59-97)	-0.51	0.75
1998 (SMRI60-98)	-0.35	0.85
1999 (SMRI61-99)	-0.75	0.17
2000 (SMRI62-00)	-0.67	0.08
2001 (SMRI63-01)	-0.47	0.35
2002 (SMRI64-02)	-0.88	-0.27
2003 (SMRI65-03)	1.13	1.31
RMS Error	1.014	
Correlation	0.724	

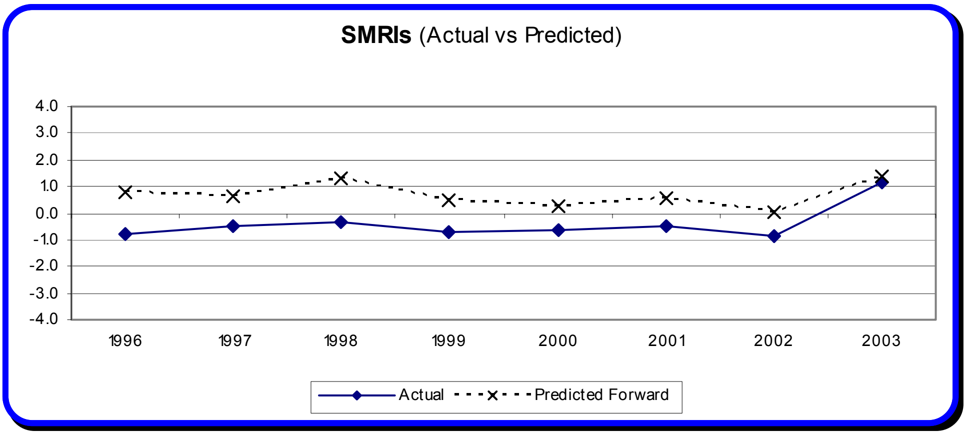

Figure 6: Graph showing Observed and Forecast rainfall values

Conclusions:

This is the new regression equation, the first such scheme for Sindh rainfall prediction. This study explores the several global and local parameters (predictors) with Sindh Monsoon Rainfall relationships. Among the predictors chosen the parameters NHT, SOI , IHP , Punjab and Balochistan average temperatures are significantly correlated with the Sindh Monsoon Rainfall Index, preceding the onset of the monsoon. The predicted values using the Forward Stepwise method is significantly satisfied.

Acknowledgement:

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