MONSOON DYNAMICS: ITS BEHAVIORAL IMPACT IN PAKISTAN'S PERSPECTIVE

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Abstract:

In this paper the dynamics and mechanism of monsoon -one of the most spectacular events of nature- have been discussed by investigating the features and components (some being permanent and the other non-permanent) of the monsoon like heat low, Southern Oscillation Index (SOI), ENSO (El Nino/ Southern Oscillation), high pressure area over Indian Ocean (IOHP), Tibetan anticyclone over Himalayas at 200 hpa, northward shifting of westerly Sub- tropical Jet (STJ), Tropical easterly Jet (TEJ), Off-shore vortices and Low-level Jet (LLJ).

Applying all these features a comparative study of good-monsoon year (2003) and bad-monsoon year (2002) over Pakistan has been made to testify the impact of these features. Also the coupling between westerly systems passing through Northern Pakistan and monsoon current has been determined in the light of research work carried out by a number of learned Meteorologists and weather experts.

Introduction:

Monsoon particularly the summer Monsoon over south and south East Asia is one of the Spectacular phenomena of nature. It has some fascinating facts attached with it.

The term monsoon means seasonal reversal of winds, which originated from the Arabic word, mausem or mawsim meaning season.

Following are the four possible definitions of the monsoon

1. The prevailing wind direction changes by at least 1200 between January & July.
2. The average frequency of prevailing wind in January & July should exceed by 40%.
3. The mean resultant winds in at least one of the months should exceed 3m/sec.
4. Fewer than one cyclone anticyclone alteration should occur every two years in either month in 5° Latitude-longitude grids (C.S. Ramage, 1971).

The countries lying between 30N°, 25S°, 30E°, 170E° satisfy these four criteria. Figure-1 shows the monsoon area.

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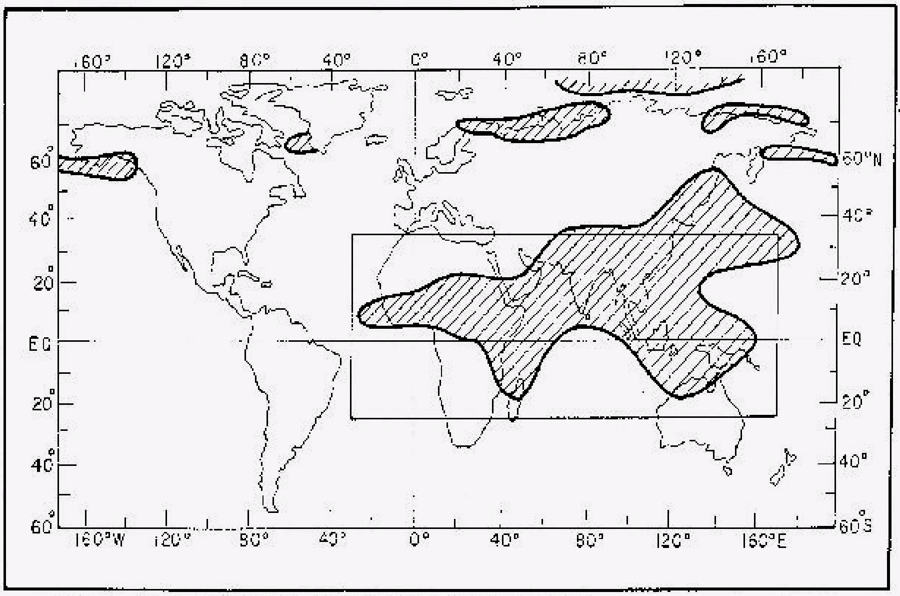


FIG. I THE MONSOON REGIME (RAMAGE 1971)

Discussion:

Halley (1686) & Hadley (1735) suggested that differential heating was the primary cause of annual cycle of monsoon circulation. Thus we can precisely say that main driving mechanisms of the monsoon are

1. The differential heating of the land and Sea.
2. Swirl introduced to the winds by the rotation of the earth.

From the reversal of winds' hypothesis we can say that generally there are two monsoon circulations

a) Summer monsoon
b) Winter monsoon

Winter monsoon (Fig-1a) is characterized by the four following quasi-permanent features

1. The Siberian anti-cyclone/High pressure area.
2. Trough at equator in the Indonesia/Australian region.
3. High pressure-cell over west Pacific and strong westerly sub-tropical Jet (STJ) aloft and
4. A zone of heavy precipitation along Malaysia and Indonesia near the equator (G.R. Gupta).

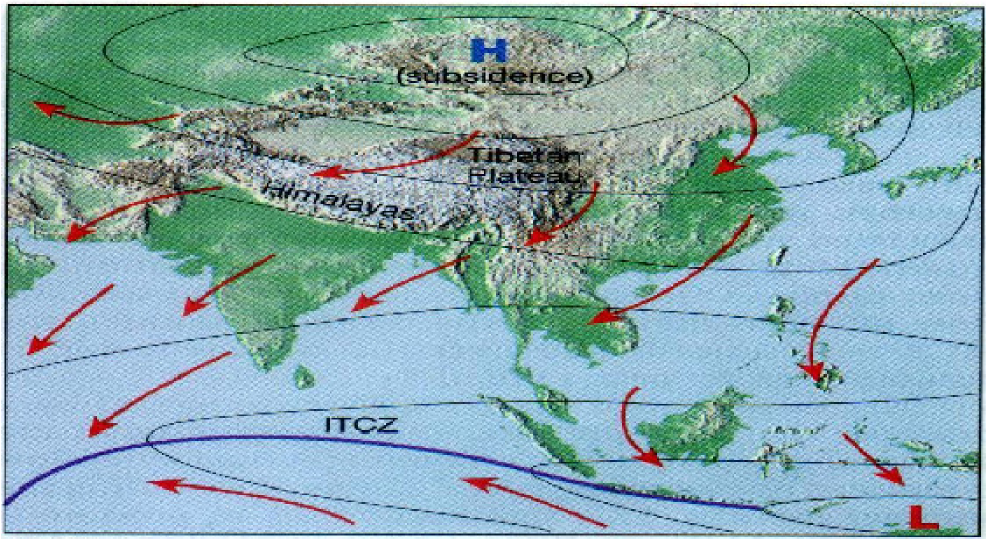


Fig-1a, Winter Monsoon

On the other hand the following semi-permanent features can characterize summer or southwest monsoon (Fig-1b).

1. The high-pressure area over the Indian Ocean near 30deg South and 50 deg East.
2. Heat low over landmass of Pakistan and Indian sub-continent with its elongated southeastward trough.
3. The Tibetan anti-cyclone at 200 hpa.
4. The Tropical easterly Jet (TEJ) and
5. Northward shifting (about north of 30 deg North) of westerly sub-tropical jet (STJ)
6. The Quasi-biennial Oscillation (QBO), being major feature of equatorial stratosphere.
7. A Low Level Jet stream (LLJ)
8. ITCZ (Inter Tropical Convergence Zone)
9. Southern Oscillation Index – SOI (difference of sea level pressure of Tahiti and Darwin.)
10. ENSO (El Nino/Southern Oscillation)

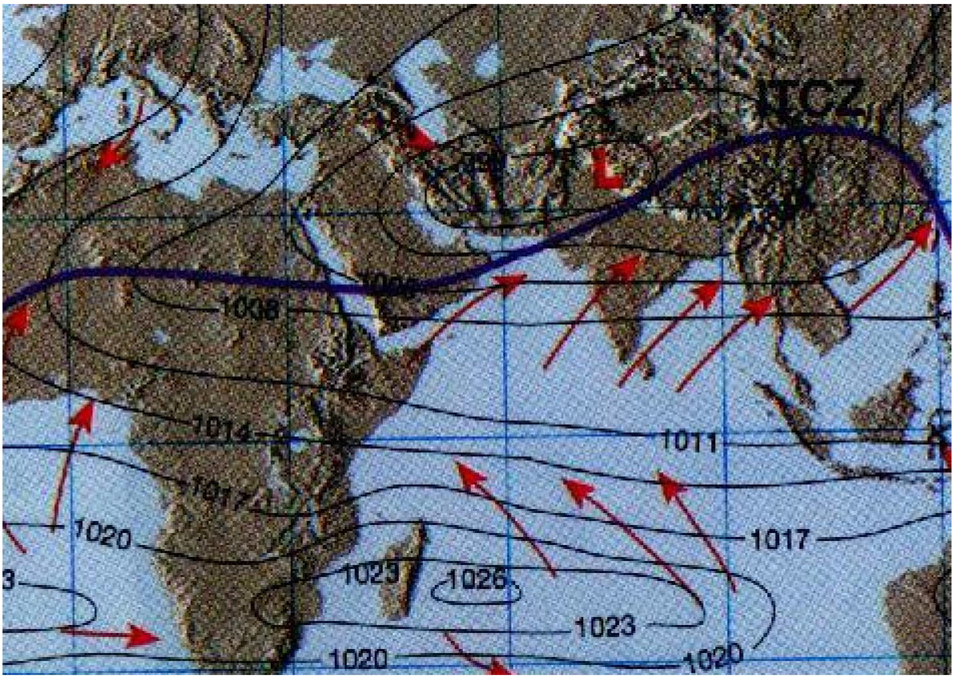


Fig-1b, Summer Monsoon

Now we take up the each of summer/southwest monsoon feature separately in detail.

Heat Low

With the northward march of sun across the equator in northern hemisphere, the continents surrounding the Arabian sea start receiving tremendous amount of heat- not only in form of sun radiation but also as heat emitted out from the earths surface. Professor Budyko from USSR estimates that the heat flux from the earth's surface in the atmosphere is equivalent of 160 watts/m2 for the month of June over arid zones of Pakistan, NW-India, Saudi Arabia and Middle East countries. This is much larger than corresponding value of 15 watts/m2 for month of December (P.K. DAS). As a consequence of this large input of power, a trough of low-pressure forms extending from Somalia northwards across Arabia into Pakistan and NW-India. Towards the end of May/early June over this region heat low is well established. It persists over there for the whole season from June towards the mid of September and a strong South westerly wind spreads over Arabian Sea, Bay of Bengal and Suburbs.

In Pakistan we observe that Sun starts scorching down the southern areas of Pakistan by the end of March or early April. April and May are the months during which soaring heat absorbed by the southern Pakistan (Sindh and south Balochistan) raises the day temperatures as high as up to plus 40s. (Table-1 shows April, May and June normal maximum temperature and extreme maximum temperatures [courtsy: Pakistan Meteorological Department, CDPC Karachi]). The peculiar geographical feature of Asian continental landmass gives rise to extreme thermal contrast between land in the north & Ocean in the south in both summer and winter, which is very crucial factor in most pronounced circulation in this part of the globe.

TEMPERATURE (°C)

Station	**NORMAL MAXIMUM**			**HIGHEST MAXIMUM**		
	April	**May**	**June**	**April**	**May**	**June**
BADIN	38.4	39.9	38.0	46.1	49.4	48.9
CHHOR	39.1	41.5	39.7	49.0	50.7	52.0
HYDERABAD	38.9	41.6	40.2	46.1	49.4	50.0
JACOBABAD	38.0	43.1	44.3	48.2	51.9	52.5
KARACHI	34.3	35.2	34.9	44.4	47.8	47.0
LARKANA	38.3	44.1	43.1	48.5	52.7	51.0
MOEN-JO-DARO	38.5	43.3	44.2	48.4	51.3	51.7
NAWABSHAH	39.3	43.5	43.2	48.5	51.0	50.5
NOKKUNDI	33.8	39.0	42.7	43.1	47.5	49.6
PADIDAN	39.0	43.6	44.2	48.3	51.5	51.5
ROHRI	37.6	42.4	43.6	47.5	49.0	51.0
SIBBI	37.7	43.5	46.0	49.4	51.7	52.6

Table-1: Normal (1961-90) & Highest Maximum Temperature of some of the Sindh & Balochistan stations

This heat low is shallow generally extending up to 850hpa. At 700hpa it is over-lain by well-marked ridge of the sub-tropics. The average sea level July pattern is shown in fig-2.

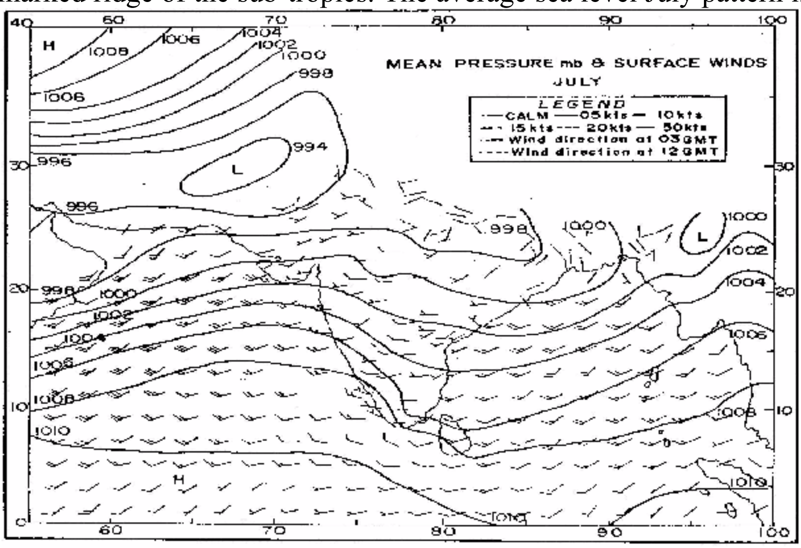


Fig-2, MSL Pressure Pattern in July over Sub-continent

It was shown by Ramage (1971) that surface pressure inside the heat low is inversely proportional to the rainfall for the areas in belt 180N to 270N (U.S. DE).

High-Pressure area over Indian Ocean (IOHP):-

Southern hemispheric circulation of the monsoon region is dominated by anti-cyclonic circulation around a high-pressure region off the coast of Madagascar. More often a high-pressure area is located in the south Indian Ocean roughly along 500E and 300S during the summer monsoon (as shown in Fig-3). This is also known as Mascarene high and

it has got a quite significant role in the cross- equatorial flow during northern summer. It gives way to low-level Jet (LLJ) with speed between 40 and 100kts, which is well marked off the African coast.

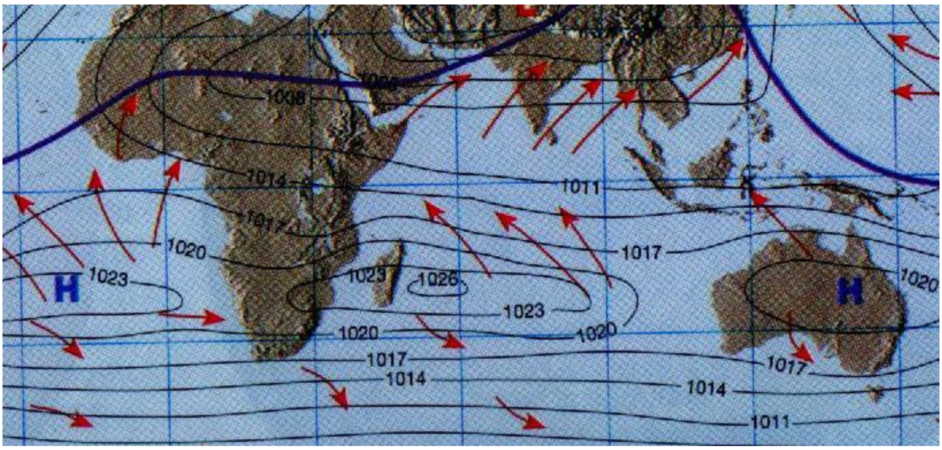


Fig-3: High Pressure area over Indian Ocean

Tibetan High at (200hpa):-

During July a ridge at 200hpa at 28°N and east of 80°E is often known as Tibetan High. Various studies show that its center is at about 980E and is distinct from the Pacific high at 140°E. Following Table-2 gives the mean position of ridge line over India and south Indian Ocean at 200hpa (U.S. DE).

Level		June	July	August	September
500 hpa	**India**	22	28	29	27
300 hpa		23	31	28	25
		December	**January**	**February**	**March**
500 hpa	**South Indian Ocean**	18	18	23	17
300 hpa		10	15	18	15

Table-2: Position of sub-tropical ridge (degree North/South)

It is said to be caused by widespread thunderstorms over southeastern Tibet in pre-monsoon months of April & May releasing, thereby considerable amount of latent heat into atmosphere through rainfall.

Basically the intense heating of Plateau and the radiational balance result in the formation of this high.

The westerly Sub-tropical Jet (STJ) is found in the north of this high and Tropical Easterly Jet (TEJ) in the south of it (Fig-4). This high is the main steering force for the monsoon systems

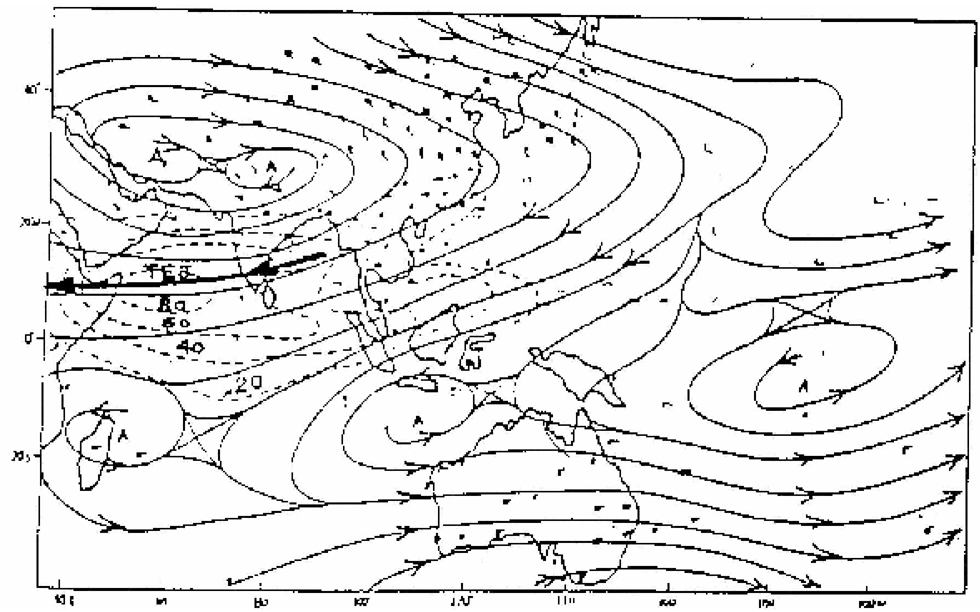


Fig-4: Mean Position of Tibetan High at 200hpa

Tropical Easterly Jet (TEJ)

South of the sub-tropical ridge over Asia, the easterly flow concentrates into a jet stream with its central region passing roughly along 13.5N° at 100 hpa over southern India and Gulf of Aden. It was 1st inferred by P.R. Krisnane Rao & P. Koteswaram in 1952. TEJ runs from east coast of Vietnam to the west coast of Africa where its location is around 10°N (Fig-5). TEJ being in normal position with above average wind speed in the jet core region leads to a good monsoon (G.S. Mandal).

A careful study of the easterly jet suggests that its core is located at higher altitude than the core of the westerly Jet in extra-tropical altitudes as such the level of maximum wind in the easterly jet is about 13km while the core of westerly jet is about 9km. Cyclonic sheer is found south of the jet and anti-cyclonic sheer is found to the north of jet. Usually east of 70E° the easterlies in jet are divergent, and down-stream west of 70°E they tend to decelerate producing convergence. This vergence distribution at upper level is associated with development of weather systems in the lower tropospheric levels in these areas.

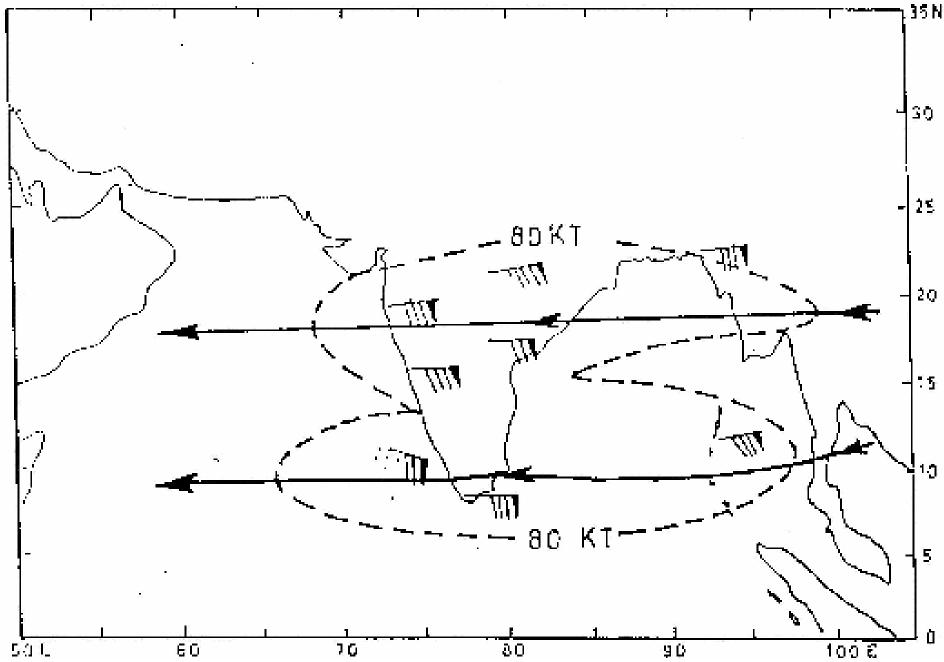


Fig-5, Tropical Easterly Jet(TEJ)

Sub-Tropical (Westerly) Jet - STJ

Another synoptic feature of onset & good monsoon is the weakening of the upper tropospheric westerly jet over northern Pakistan & adjoining India and the ultimate shift of sub tropical westerly Jet (STJ) to the north of Himalayas. The northward shifting of STJ gives way to the more penetration & advancement of monsoon towards higher latitudes.

The Quasi-biennial Oscillation (QBO)

QBO – Quasi biennial oscillation is a major factor of the equatorial Stratosphere. At levels between 60hpa & 10hpa, alternative spells of easterly & westerly winds are observed with periods of two years or slightly above. The analysis of the power spectrum of monsoon rainfall has revealed that rainfall has got some association with QBO.

Low Level Jet (LLJ).

Besides the TEJ there is yet another Jet flowing intermittently over Somali coast, Arabian Sea & peninsular India. This is named as low-level Jet–LLJ (Fig-6). LLJ is taken to represent a narrow current in the monsoon field in the lower levels of atmosphere with wind speeds above 40-60kts.

Reiter (1961) & Joseph (1966) brought out the existence of LLJ over Indian peninsula.

The core of the LLJ is roughly 250-350km wide, 600-900km long & one km deep (Y.E.A. Raj).

Flowing over Arabian Sea & Peninsula India LLJ causes convergence ahead. Further there world be a generation of positive relative vorticity in the northern side of the Jet core & negative vorticity in the southern side. Thus the northern sector ahead of an approaching LLJ core could be a good favoured zone for good rainfall.

Okola & Asnani (1982) having carried out the analysis detected relation between monsoon rainfall over India & intensity of prominent anticyclone southeast of Madagascar in Indian Ocean called Mascarene High. Hence most probably LLJ is triggered by the outflow from this anti-cyclone.

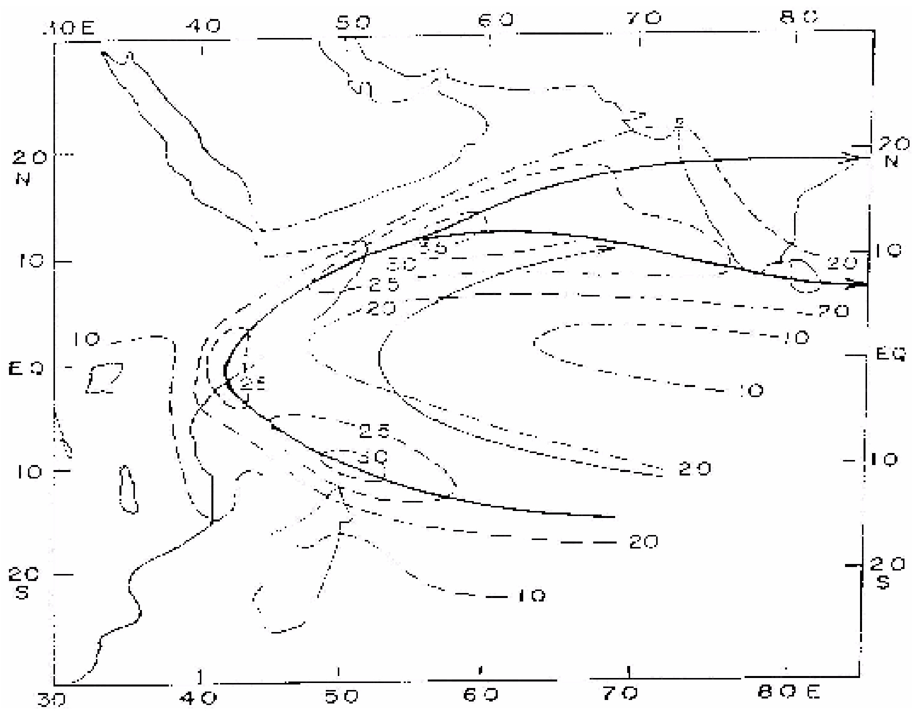


Fig-6: Low level cross-equatorial Jet(wind speed in knots)

ITCZ-Inter Tropical Convergence Zone

It is the narrow zone where air masses, from northern and southern hemispheres moving towards the equator, converge producing shear cyclonic vorticity. Over western Africa the ITCZ is often recalled as “Inter Tropical Discontinuity” (ITD) because the weather that is associated with the ITCZ over east Africa is different from what is observed over western coast of Africa. The changing position ITCZ is singularly responsible for the seasonal variations of rain over east Africa.

During the northern hemispheric summer, the ITCZ moves to the north of Equator. Probably it merges with an extended trough in the lower troposphere but there is another opinion as well that it looses its identity.

The ITCZ migrates seasonally as for as 15°N or more of equator in some places. Its fluctuation is maximum over the Indian region during monsoon season (Fig-7a, b). The fluctuation of ITCZ over monsoonal region was studied by Sikka and Gadgil(1980) Gadgil(1982).

According to them there are two cloud zones between 70°E and 90°E one is the continental in the monsoon zone north of 15°N and the other being the Oceanic over the equatorial regions. Active spell of one is generally associated with the weak spells of the other and vice-versa.

According to Gadgil, during the onset phase of the Southwest monsoon ITCZ shifts northwards leading to the establishment of the monsoon zone. It fluctuates with monsoon zone for a period of about four weeks.

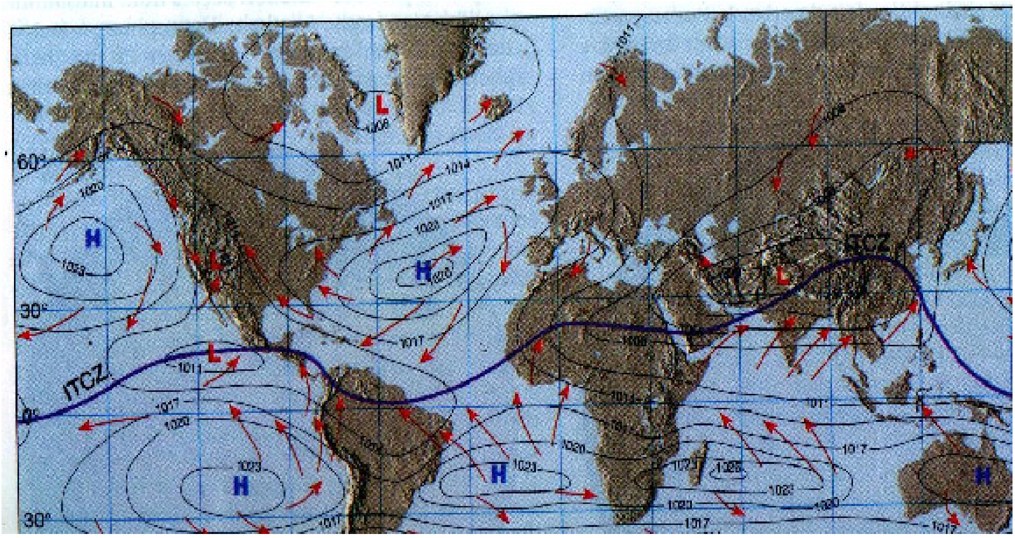


Fig-7a: Mean position of ITCZ in July

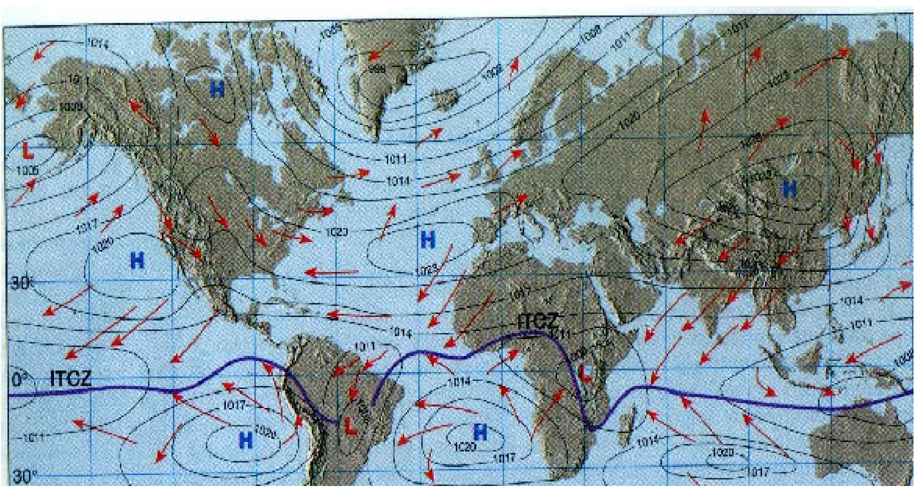


Fig-7b, Mean position of ITCZ in January

Southern Oscillation Index (SOI)

Yet another equally important phenomenon having notable effect on summer (southwest) monsoon is Southern Oscillation. The intensity of (SOI) is represented by the pressure difference between Tahiti in French Polynesia and Darwin in northern Australia. Discovered by Sir Gilbert walker Southern Oscillation postulates "a See-Saw weather pattern between Pacific Ocean and Indian Ocean extending from Africa to Australia". He discovered that when pressure tended to be high over Pacific Ocean it tended to be low over Indian Ocean.

With pressures being inversely related to rainfall, the prevailing low pressures over Indian Ocean in the winter months is an indication of approach of good monsoon in summer. SOI has a period of varying from 3 to 7 years and consequently pressure departures and their trends are considered to be better predictors than absolute values of pressure. The El Nino event in the preceding winter is suggestive of a strong Walker circulation and weak monsoon.

EL Nino/Southern Oscillation (ENSO)

Ocean currents, being significant for Navigation, also have an important effect on climate. In the eastern Pacific a strong cold Peruvian current flows equatorward along the coast of Peru and Ecuador. This causes the upwelling and as a result a cold current starts flowing westward. During this state a high pressure prevails in eastern Pacific near Peru coast and low pressure in western Pacific over north Australia. But near the end of each year a weak warm counter current flows southward along coast of Peru and Ecuador, replacing the cold Peruvian current. This is known as El Nino (Fig-8a).

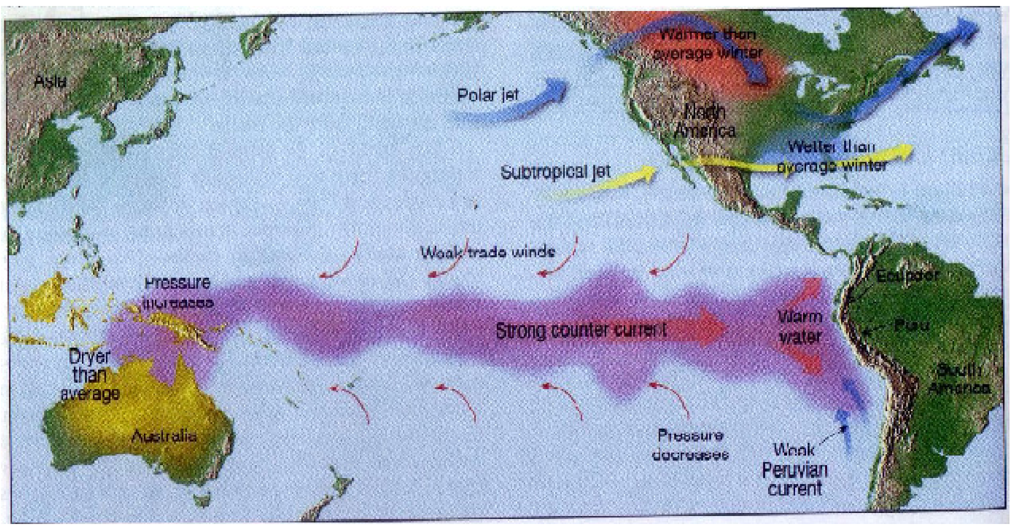


Fig-8a: El Nino

Major El Nino events, like the one in 1982 and 1983, are intimately related to the large-scale atmospheric circulation. With the occurrence of El Nino the barometric pressure drops over large portion of the southern Pacific, whereas in western Pacific near Indonesia and north Australia the pressure rises. This reverse trend of pressure distribution in Pacific weakens the Southern Oscillation and hence the cross equatorial flow is dampened which results in weak monsoon. But this is not the case always as the study advanced by PK.DAS explains that by examining the history of Indian rainfall from 1875 to 1985 shows about 43 years of deficient monsoon rain but only 19 of the 43 deficient years were El Nino years. This indicates that there are other factors as well, than EL Nino, which cause a deficiency in monsoon rain. In the period from 1875 to 1985, there were only 6 so years that El Nino happened but rainfall wasn't deficient. It hence proves that EL Nino has got same association with poor or indifferent monsoon.

With the end of El Nino event the pressure difference between these two regions swings back in opposite direction. i.e. low pressure over northern Australia in west Pacific and high in eastern Pacific (fig-8b). This See-Saw pattern of atmospheric pressure between eastern and western Pacific is called Southern Oscillation. It is an inseparable part of the El Nino warming that occurs over central and eastern Pacific every 3 to 7 years. Therefore this phenomenon is often called El Nino/Southern Oscillation or ENSO (Edward J. Tarbuck & Fredrick K. Lutgens).

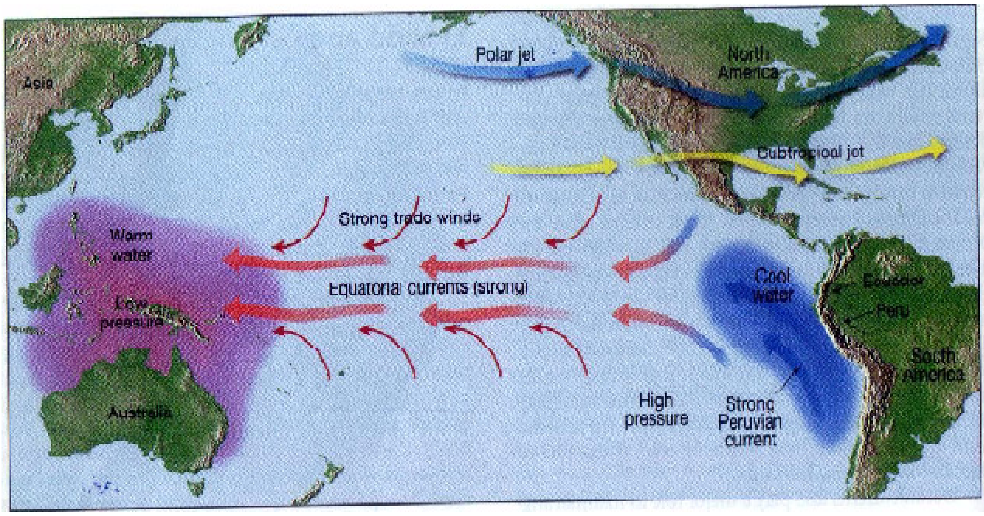


Fig-8b: Normal conditions

In summary the effects of El Nino on world climate are widespread and variable, as is said "There is no place on earth where weather is indifferent to air and Ocean currents in the tropical Pacific. Southern Oscillation and El Nino events associated with it are now believed to have a significant influence on the state of weather and climate almost everywhere"(J. Murray Mitchell, 1983).

Hadley and Walker Cells

Dr.J.Bjerknes from Norway, explaining the Walker cell as a feed back from Oceans, suggests that main drive for the Walker cell is the difference in temperatures of the Sea Surface (SST) between Indonesia (warm) and eastern Pacific Ocean (cold). Cold costal waters off the Peru and Ecuador coasts are generated by the upwelling i.e. replacement of surface waters by colder water from greater depths. The warm

SSTs at Indonesian sector induce the greater cloudiness which, in turn, cuts off the input from solar radiation, thereby reducing the drive behind Walker circulation (P.K.DAS). This weakening of the drive behind the Walker circulation causes the rise in SSTs at the eastern Pacific because of the lesser upwelling and resultantly the difference in western and eastern Pacific SST's gets narrowed.

Summer and winter monsoon of Asia being principal monsoon of the world appear to be dominated by the circulations that are either aligned in a north–south or east-west direction. The rising branch of each circulation is located near source of heat while descending limb occurs over a heat sink. These are known as Hadley and Walker cells.

For the Asian summer/Southwest Monsoon Tibetan Plateau acts as an elevated heat source. The ascending air above the source gradually spreads southwards to join a descending limb over north India Ocean near the Mascarene high. The southwesterly winds at the surface form the return current to complete the Hadley cells. In the addition there is an east-west Walker cell appears to influence the summer monsoon. The ascending branch of Walker cell is located over Indonesia where heat source is generated due to convection and heavy precipitation. The descending limb of the Walker cell is located over the semi-arid region of Pakistan, Northwest India and Middle East.

The performance of Asian summer monsoon is often determined by the relative importance of Hadley and Walker cells. Good monsoon appear to be associated with the more intense Hadley cell and relatively weak Walker cell, while on the other hand, poor monsoon occur when Walker cell is strong and Hadley cell is weak.

Mid-Tropospheric Cyclones (MTC)

The peculiar circular vortices are formed during monsoon between 3 to 6 km with their largest amplitude near 600mb over western Ghats of India. The dimensions of these vortices are roughly of the order of 300km horizontally & 3km vertically (P.K.DAS). The peculiar feature of these vortices is that they are only confined to the middle Troposphere and usually are not visible at surface.

The structure of mid-Tropospheric cyclonic vortex reveals that there is a core of warm air above middle level and slightly cold core below that level. Unlike the Bay of Bengal depressions, these vortices are slow moving and appear to remain quasi-stationary for many days.

The formation of these vortices results in heavy rain (even something like 20cm in 24hrs) over northern sector of west coast of India and south/southeastern Sindh of Pakistan.

Trigger Mechanism:

Long vertical shear presence of disturbance in Bay, moisture flux or cumulus activity in existing weak vorticity area and latent heat (once MTC is formed) are the triggering mechanism.

Offshore Vortices/Troughs

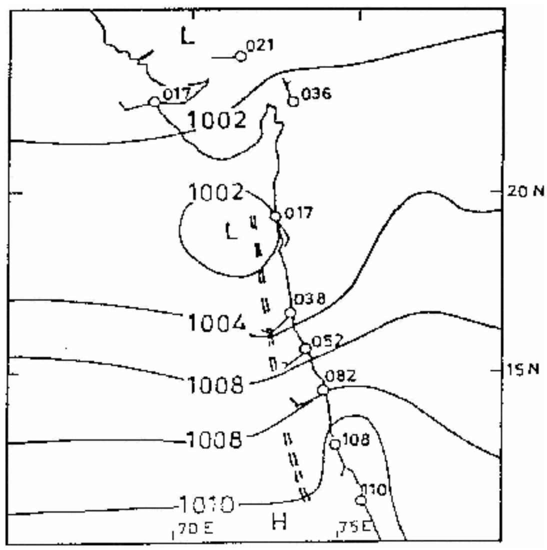
These are sub-synoptic scale systems with horizontal scale of 100-150km and generally observed off the west coast of India during months of monsoon producing very heavy rainfall along west coast of India.

Being very shallow system they are generally confined to levels below 850hpa. They are detected by weak easterly/southerly winds at coastal stations.

Offshore vortex formation takes place when southwest winds hitting the western Ghats (mountain peaks) don't have enough energy to climb over tended to be deflected round mountain and a return current is resulted (fig-9).

Often the Offshore Trough and Offshore Vortex form off Kerala–Karnataka coast and move northward along the west coast of India. Moving northward sometimes up to northeast Arabian Sea they give birth to monsoon depression in the Arabian Sea.

Southeastern coast of Pakistan's Sindh province often receives very huge amount of rainfall with northward movement of offshore vortex/trough.



Fig–9 Offshore Vortex/ Trough (August18,1987)

CASE STUDY –PAKISTAN (MONSOON -2003 & 2002):

Pakistan does have location stretched from SW to NE (61°E to 77°E and 23.5°N to 37°N). It experiences some unique but diversified climatic pattern round the year. In the extreme north we experience minimum temperature as low as -25°C and in southern sandy desert areas summer temperatures rise as much as up to 55°C. Perhaps it's the only country on the globe that undergoes such a huge temperature contrasts in a year.

Pakistan is an agriculture country, so its socio-economic life is very much dependent on good and sufficient rainfall.

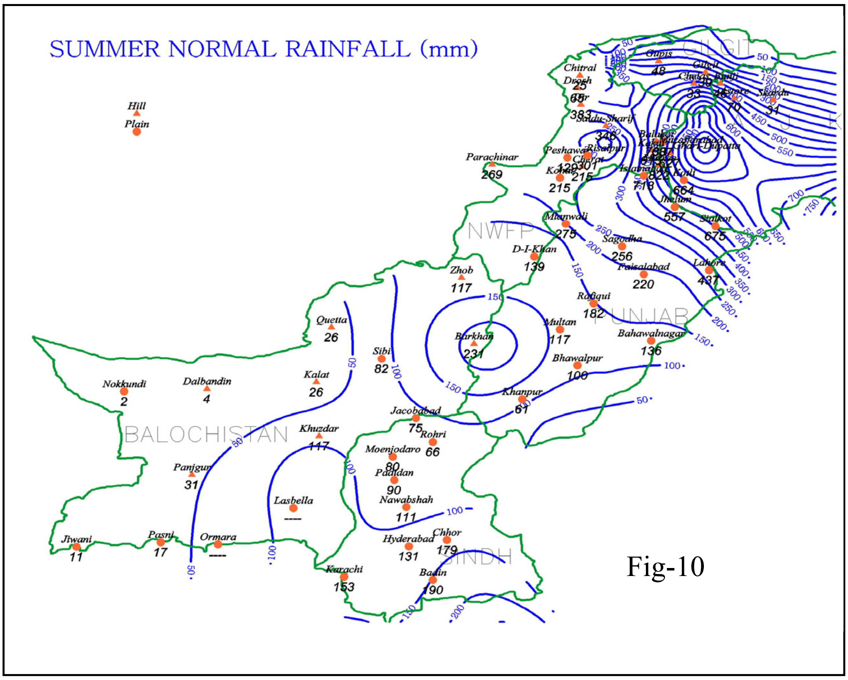


Fig-10

Monsoon is undoubtedly the principal contributor (about 65% to 70%) of the total annual rainfall. Therefore people of Pakistan, by and large, take a sigh of relief when they see enough amount of precipitation pouring down from the skies and they get worried when come across the deficient rainfall. Monsoon sets on in Pakistan with the beginning of July and towards the end of September this prevails. In addition to the monsoon factors mentioned above with regard to Pakistan more frequent observations are that

1. the coastal cities of Pakistan like Karachi, Ormara, Pasni and Thatta etc remain under the grip of thick layer of low clouds under the influence of strong southwesterly flow from north Arabian Sea on to land.
2. this strong SW-flow sometimes is so well organized and well directed at lower levels (850 to 700 hpa) that entire eastern belt of country (running north – south) is fed with considerable amount of moisture, which when gets interacted with southeasterly deflected moist monsoon current yields heavy downpour.
3. And the last but not the least is the passage of westerly trough through northern areas of Pakistan. When westerly wave couples with the above mentioned two currents the result is in triplicates. In such case moisture pumping gets underway from three reservoirs and sometimes torrential and devastating rainfall happens to occur. The most glaring example of such a case is July 23, 2001 when capital city Islamabad experienced all time record-breaking rainfall of 620mm in just 12 hrs.

Figure-11, at a glance, gives a view of variation of monsoon rainfall during past thirteen years (1991-2003)

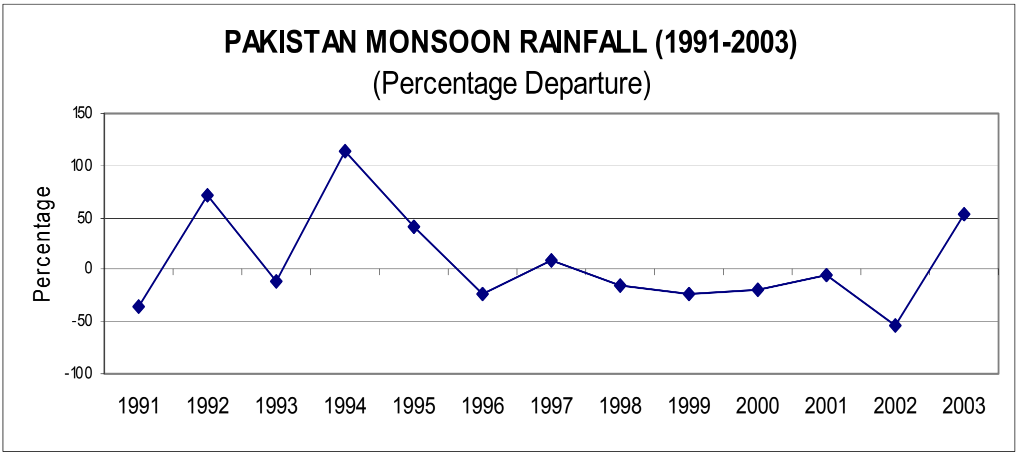


Fig-11

In this perspective for comparative study I have picked up two particular years 2002 and 2003, being bad (poor) and good monsoon years respectively. It is evident from the Figure-12 that 2002 has seen about 50% below normal monsoon rainfall while quite contrarily 2003 monsoon has brought 50% above normal rainfall.

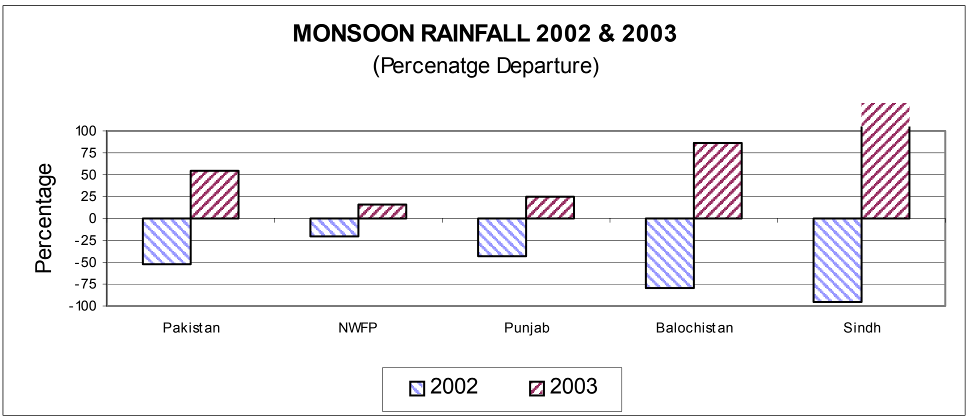


Fig-12

2002 monsoon being largely deficient one, which has worsened the already drought-hit country but fortunately 2003 has done the compensation. Some images given here depict the true situation in July 2003.

August 7, 2003 (Badin)

July 29, 2003 (Karachi)

Table-3 illustrates the Normal (19961-90) and actual monsoon rainfall over Pakistan during the seasons 2002 and 2003 (PMD, CDPC Karachi).

MONSOON (Jul-Sep) RAINFALL (mm)			
	Normal	**2002**	**2003**
Pakistan	137.5	64.2	211.0
NWFP	225.2	180.5	259.6
Punjab	235.7	131.3	296.3
Balochistan	58.8	12.0	108.9
Sindh	127.5	6.4	295.5

Table-3

PMD furnishes the seasonal monsoon forecast for Pakistan by using the following multiple regression equation

$$\text{Pakistan Monsoon Rainfall} = 0.3576 \times A - 14.3989 \times B - 0.7621 \times C - 0.8147 \times D + 0.3902$$

Where

A = South American Pressure
B = Equatorial Pressure
C = Temperatures Range in Punjab-(Pakistan)
D = Western Himalayas Snow Accumulation

CONCLUSION:

The application of the features we have just discussed on two particular years 2002 and 2003-monsoon rainfall in Pakistan are summarized in Table-4, which shows:

1. ***Tibetan High*** at 200 hpa in both seasons latitudinally located almost at same position (25N-32N and 26-32N) but in 2003 it was a bit more shifted westward (78E-90E) and in 2002 monsoon its ridge line was more on eastern side (90E-110E). Evidently the longitude 90E (its western edge in 2002 monsoon) was its starting point in 2003 monsoon as it was hovering between 70E to 90E longitude wise. Hence its more westward-orientation produced far far better results in Pakistan.
2. ***Heat Low*** with mean central pressure value 988-992 hpa during July 2003 was much lower than that in July 2002 (992-994 hpa). This means in July 2003 it was more pronounced than that of July 2002.
3. In July 2003, from the available data, there were 11 occasions of formation of ***Off-shore Vortex*** around 15N & 70E, while July -2002 lags too much behind in this aspect with only one formation of like activity.

Mean July synoptic monsoon components in two respective years

		Good Monsoon year- 2003 Mean July monsoon factors (Synoptic features)		**Bad Monsoon year- 2002 Mean July monsoon factors (Synoptic features)**	
		No of days	Mean position	No of days	Mean position
1	Tibetan High (200hpa)	28	25-32°N 78–90°E	27	26-32°N 90-110°E
	Viz well in coincidence with its mean position around 28°N/80°E				
2	Heat Low	27	988-992 hpa	30	992-994 hpa
	Viz more pronounced than the Mean July position of Heat low-(994hpa)				
3	Off Shore Vortex/Trough (850,700hpa)	11	15°N and 70°E	1	22°N and 70°E
4	Mid Tropospheric Cyclone–MTC (500hpa)	6	15°N and 70°E		
5	Low Level Jet-LLJ (850, 700hpa) over western Ghat of India	11	SW'ly20-35KTS	14	W/SW'ly 20-30kts

Table-4 Comparison of two Monsoon Years (2002-2003)

4. ***MTC- the Mid-Tropospheric Cyclone*** (500 hpa) with mean position around 15N & 70E is yet another features which developed six times in July 2003 and not a single such occasion was there in July 2002.
5. ***Low Level Jet (LLJ)*** was also a bit more pronounced both direction and speed wise in July 2003 than that in July 2002 over western Ghat of India. It was mainly from southwest with speed between 20-35 KTS. That in July-2002 was mainly directed from west/southwest with a lesser force (20-30 KTS).

Well this post-mortem type of conclusion encourages to say that above discussed features fulfill the criteria to become the parameters of good monsoon at least over Pakistan.

But admittedly this study was more specific about 2003 and 2002-monsoon years in Pakistan and it needs to be carried out forward by analyzing more data.

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