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Some aspects of the influence of North West Pacific systems on Indian Summer Monsoon Rainfall

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ABSTRACT

Failure of southwest monsoon rainfall during 2002 highlighted again the need for examining the impact of intense low pressure systems (Tropical depression and above) over North West Pacific (NWP) on Indian Summer Monsoon Rainfall (ISMR) with a longer series of data. Month wise tracks of NWP intense low pressure systems, located west of 140°east from June to September for 38 years from 1963 have been considered. These include 27 All India normal/excess and 11 deficient monsoon years. These data have been analyzed with All India monsoon rainfall (AIMR) of the same years. It has been observed that NWP systems located west of 120°east and AIMR are positively correlated with correlation coefficient (CC) of +0.368. When an NWP system is located west of 120°east and a low pressure area (LPA) is observed over the Bay, monsoon depression (MD) forms over the Bay, otherwise an LPA forms over the Bay. Under these conditions east-west trough is seen up to 500 hPa and it continues up to the NWP system. The situation enhances the rainfall activity over India. It has been also observed that excess cyclone genesis over Northwest Pacific during summer monsoon is not the cause of monsoon failure over the country. Correlation coefficient (CC), computed between AIMR and total number of systems that crossed 30° north, are negatively correlated (-0.438). Both types of correlation coefficients suggest that NWP systems influence ISMR in both ways but they can not alter normal/ excess monsoon conditions into deficient monsoon conditions and vice versa.

INTRODUCTION

The failure of southwest monsoon is related to many regional and global anomalies in Circulation, Sea surface temperature and cyclone genesis as summer monsoon is a perturbation on global scale. The past studies highlight the role of NWP weather systems in modulating the performance of Indian summer monsoon. Southwest monsoon extends eastwards as a distinct current (winds) up to about 30° north (N)/ 140°east (E), which is clearly seen up to 850 hPa constant pressure chart. This is the reason for considering NWP systems up to 140°E in this study. During the year 2002, 18 NWP systems were observed between June to September west of IDL, which were also considered responsible for deficient rainfall over the country during the year. Attempts have been made to examine the positive and negative impact of NWP systems on ISMR by considering 38 years data for 27 normal /excess and 11 deficient All India monsoon rainfalls for a period from 1963 to 2004. In this study, percentage departure from normal rainfall has been considered as +11% and more for excess, +10% to -10% for normal and -11% and less for deficient rainfall.

DATA

Month wise tracks of NWP systems (June- September) for 38 year period have been collected from Joint Typhoon Warning Centre Guam website. These data include 27 normal / excess rainfall year and 11 deficient monsoon year. AIMR data for summer monsoon have been collected from India Meteorological Department (IMD) website. The details of monsoon activity and relevant information have been collected from the weather summaries published in Mausam and Weekly Weather Report published by IMD.

PREVIOUS STUDIES

Joseph (1990) observed that in excess monsoon years, cyclone genesis does not occur during the first four weeks after the onset of monsoon over Kerala. He had further stated that in deficient monsoon years only the first two weeks are free from cyclone genesis. He had considered NWP systems, which formed west of International Date Line (IDL). Rajeevan (1993) had observed that AIMR and number of typhoon days over NWP from June to September are significantly and negatively correlated. He considered NWP systems, which formed west of IDL and south of 35°north. He has further mentioned that on an average 15% of MD, which form during southwest monsoon season, are remnants of typhoons moving westwards and emerging into the Bay. Raman (1955) associates breaks with a typhoon or its remnant in the western Pacific moving to the north of latitude 30°N, provided there is neither a depression or typhoon in the China Seas, south of 30°N nor unsettled conditions or a depression prevailed in the Bay of Bengal. Here specific importance to 120°E (China Seas) is noticed. Ramanna (1969) observed that during 60 years period around 20% of the cyclonic systems had formed in the Bay between 15° and 25°N after the cyclonic systems of the South China Sea crossed the coast in the same latitude during July and August. These factors contributed to monsoon deficiency over central and northwest India. Importance of south of 25°N as well as 120°E (South China Sea) is highlighted here for formation of cyclonic systems over the Bay. Mohanty & Dash (1994) observed that the flow entering the northern hemisphere during the summer monsoon months is concentrated at three regions at about 045°-055°E, 080°-090°E and 100°-120°E corresponding to the three branches of monsoon viz. Arabian Sea, Bay of Bengal and south China Sea. They further observed that the peaks of the flow are at 050°E, 080°E and 105°E. Here again, their observations confirm a possible link between an NWP system reaching west of 120°E and formation of a MD or an LPA over the Bay. Joseph, Rajan & Suraj (2001) have observed that when monsoon sets in over Kerala a strong cross equatorial air current gets established in the lower troposphere over the Indian Ocean and south-Asia at about 850 hPa. This monsoon current transports moisture generated over Indian Ocean to monsoon rain area. Therefore strength of 850 hPa winds is important for transporting moisture generated over Indian Ocean to monsoon rain area. Dash & Mohanty (1999) observed that westerly wind maxima at 850 hPa were lowest along Somalia coast during 1987, where as in excess year 1988 they were large compared to normal and deficient monsoon years. Therefore cross equatorial flow was weak in the lower troposphere during 1987.

METHODOLOGY

NWP systems located west of 140°E and east of 140°E up to IDL (Table 1 and 2) from June to September have been counted separately for 27 normal and 11 deficient all India monsoon years. When an NWP system reaches west of 140°E, follows westerly to northwesterly track, the depth of ITCZ extends upwards up to 500 hPa in constant pressure charts over India and neighbourhood and monsoon rainfall activity gets enhanced due to increased convergence along the trough line. The ISMR depends upon the strength of monsoon current, position of monsoon trough and other synoptic situations over the country. When, the NWP system follows westerly or north westerly track it tends to increase rainfall activity in India. It has been observed that if an NWP system is located west of 120°E and if there is an LPA over the Bay, probability of its intensification into a depression increases. There were 34 such cases of formation of MD over the Bay during 20 years period (Table 3). Again during 14 years period, 34 monsoon lows formed over the Bay when an NWP system reached west of 120°E. South China Sea branch of monsoon current is concentrated between 100°-120°E; as a result more convergence would be noticed over the Bay when the NWP system reaches west of 120°E because of strong monsoon flow in the area. The movement and position of an NWP system could be utilized as indication for strengthening of monsoon over India. To examine the relationship between AIMR and NWP systems located west of 120° during June to September, correlation coefficient (CC) has been computed considering these two variables for 38 years data (1963-2004). NWP systems, which followed northeasterly track, have been omitted. It has been observed that they are positively correlated with CC +0.368. To examine the impact of NWP systems crossing 30°N on AIMR, CC between AIMR and total number of systems that crossed 30°N (even moving in North West direction: Table 4 and 5) have been computed for the above period. It has been observed that these are negatively correlated with CC –0.428.

Number of NWP systems observed during southwest monsoon and AIMR

Southwest monsoon set in over Kerala on 26th May in 1988. During the month of June, four NWP systems were observed west of 140°E from 1st June onwards of which, two systems recurved (Figure 1 and

Table 1. Formation of NWP systems south of 30° north and up to 140° east/ IDL during All India Normal/ Excess monsoon years.

Year	June	July	August	September	Total up to 140° east	Total up to IDL
1963	4	3	3	3	13	16
1964	1	7	5	7	20	24
1967	1	5	5	2	13	22
1971	2	7	3	5	17	20
1976	2	4	4	2	12	15
1977	1	4	1	4	10	12
1978	3	3	6	4	16	20
1980	1	4	2	4	11	16
1981	3	4	4	2	13	19
1983	1	3	4	3	11	12
1984	2	3	7	1	13	18
1985	3	1	7	5	16	17
1988	4	2	1	5	12	18
1989	2	7	2	5	16	23
1990	4	3	5	6	18	20
1991	1	4	5	6	16	18
1992	2	5	5	2	14	20
1993	2	5	5	5	17	21
1994	2	9	5	4	20	27
1995	1	3	6	7	17	19
1996	0	5	4	5	14	23
1997	2	3	5	2	12	21
1998	0	2	4	7	13	14
1999	1	4	7	5	17	20
2000	1	6	6	4	17	24
2001	3	2	3	3	11	19
2003	2	2	5	2	11	11
Total	51	110	119	110	390	509
A.M.	1.9	4.1	4.4	4.1	14.4	18.9

Table 2. Formation of NWP systems south of 30° north and up to 140° east/ IDL during All India Deficient monsoon years.

Year	June	July	August	September	Total up to 140°east	Total up to IDL
1965	4	5	4	5	18	22
1966	1	5	6	3	15	19
1968	2	3	5	4	14	16
1972	2	5	3	4	14	20
1974	4	3	7	3	17	20
1979	1	4	4	4	13	15
1982	3	4	4	6	17	18
1986	2	3	3	2	10	12
1987	2	4	3	3	12	17
2002	2	6	5	4	17	18
2004	4	2	4	4	14	19
Total	27	44	48	42	161	196
A. M.	2.5	4.0	4.4	3.8	14.6	17.8
B. F.	51	110	119	110	390	509
Total	78	154	167	152	551	705
A. M.	2.1	4.1	4.4	4.0	14.5	18.5

03) and two reached west of 120°E (Figure 2 and 4). The AIMR for the month of June was +6.8% (normal) and that during the season were +19.3%. During 1963 and 1990 four NWP systems were observed during the month of June, but AIMR for the season had been recorded as normal both in1963 (-2.1%) and 1990 (+6.2%). Out of 27 normal or excess monsoon years, only during two years i.e. in 1996 and 1998 no NWP systems were observed west of 140°E during the month of June. Therefore, the observation made by Joseph (1990) regarding cyclone genesis during June for excess or deficient monsoon rainfall years are not valid when data for a longer period is considered. During 1964 and 1994 monsoon season 20 each NWP systems were observed west of 140°E, which are the highest numbers in 38 years study period. During these two years, 24 and 27 systems were observed respectively up to IDL. AIMR had been recorded normal during 1964 and excess during 1994 (1964: +9.8%, 1994: +12.5%) respectively. In the month of July 1994, nine NWP systems were observed west of 140°E, which is highest again in 38 years study period. Even then excess rainfall (20.8%) was recorded during the month. During the worst monsoon year 2002, 17 systems (July- 7) were observed west of 140°E; where as only 10 systems were observed during the deficient monsoon year 1986. On an average 14.4 (18.9 up to IDL) and 14.6 (17.8 up to IDL) NWP systems were observed respectively west of 140°E during normal and deficient monsoon years. Therefore, there is no difference between number of NWP systems which form during normal and deficient monsoon years either west of 140°E or up to IDL. As such, NWP systems can not be considered for deficient monsoon rainfall over the country whenever they are observed more in numbers during a month or season.

Table 3. NWP systems and formation of monsoon depressions in the Bay.

SRL. NO.	Date/Time in UTC	NWP system ID	Position in degree (N/E)	Depression in Bay on/ near (N/E)
1	08.09.1963 / 0000	13w	19.7/109.3	8th East central Bay
2	03.07.1964 / 0000	03w	21.0/107.0	3rd 21.0/089.5
3	09.08.1964 / 0000	12w	23.2/112.3	9th North Bay
4	23.09.64 / 0000	22w	17.3/104.9	23rd Head Bay
5	27.09.1964 / 0000	25w	16.1/108.0	27th West Central (WC) Bay
6	27.07.1966 / 0000	08w	22.5/106.0	28th east of Kolkata
7	31.07.1967 / 0000	11w	17.4/113.3	31st North Bay
8	16.08.1967 / 1200	14w	22.0/110.0	18th 21.0/090.0
9	11.08.1968 / 0000	08w	18.3/116.8	11th North Bay
10	21.08.1968 / 1200	09w	22.2/114.3	22nd North Bay
11	09.09.1968 / 0000	12w	20.8/108.6	10th North Bay
12	26.07.1971/ 0000	18w	23.5/119.7	26th Head Bay
13	27.09.1971/ 1200	29w	17.8/119.8	27th at 1200 Central Bay
14	14.06.1974 / 0000	06w	20.1/ 105.4	15th Central Bay
15	12.08.1974 / 1200	14w	25.9/117.8	13th North Bay
16	06.07.1979 / 0000	06w	21.6/111.5	6th 19.5/ 089.5
17	06.08.1979 / 0000	09w	22.3/ 092.0	6th 21.0/ 090.0
18	17.07.1982 / 1200	09w	21.3 /109.2	18th North West (NW) Bay
19	23.06.1983 / 1200	01w	12.8 /115.3	23rd at 1200 18.5/086.0
20	19.9.1985 / 0000	18w	16.2 /114.2	19th at 1200 19.0/089.0
21	11.06.1989 / 1200	05w	22.0 /105.0	12th NW Bay
22	21.07.1989 / 1200	10w	15.0 /113.4	21st at1200 Central Bay
23	20.08.1990 / 0000	13w	25.4 /119.7	20th NW Bay
24	14.09.1995 / 1200	19w	13.7 /114.8	14th at 1200 East Central Bay
25	20.08.1997 / 0600	17w	18.7 /117.3	20th 20.5/087.5
26	23.09.1997 / 0000	22w	15.9 /111.3	23rd 15.5/082.5
27	23.08.2000 / 0000	19w	16.5 /106.2	23rd 16.5/083.5
28	31.08.2000 / 1800	21w	22.4 /115.1	1st NW Bay
29	25.07.2003 / 0000	09w	23.5 /106.1	21st 21.0/089.0
30	27.08.2003 / 0000	13w	22.3 /105.2	27th 20.5/088.5
31	11.06.2004 / 0000	08w	12.7 /116.2	11th 15.5/90.0
32	12.09.2005 / 0000	15w	24.5 /119.0	12th 20.0/088.0
33	02.08.2006 / 0000	07w	18.2 /115.2	2nd 20.5/087.5
34	11.08.2006 / 0000	10w	20.4 /112.8	12th 21.0/088.0

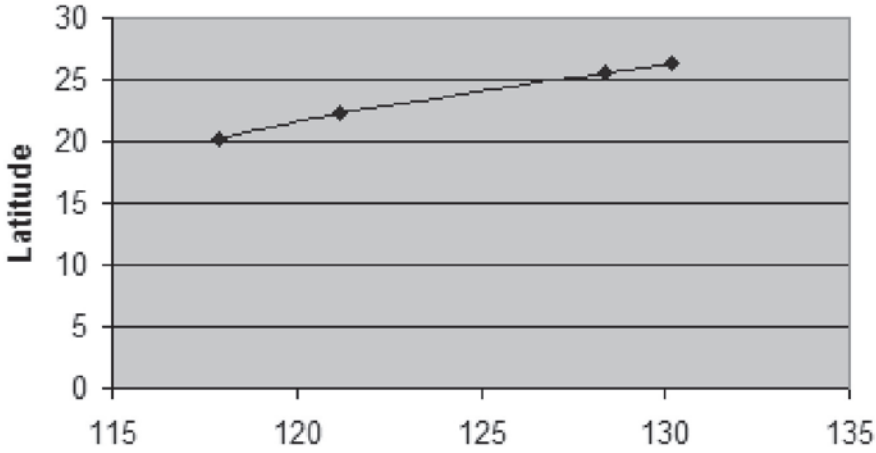

Figure 1. Track of 02w from 117.8 east between 1-3 June 1988 (Longitude).

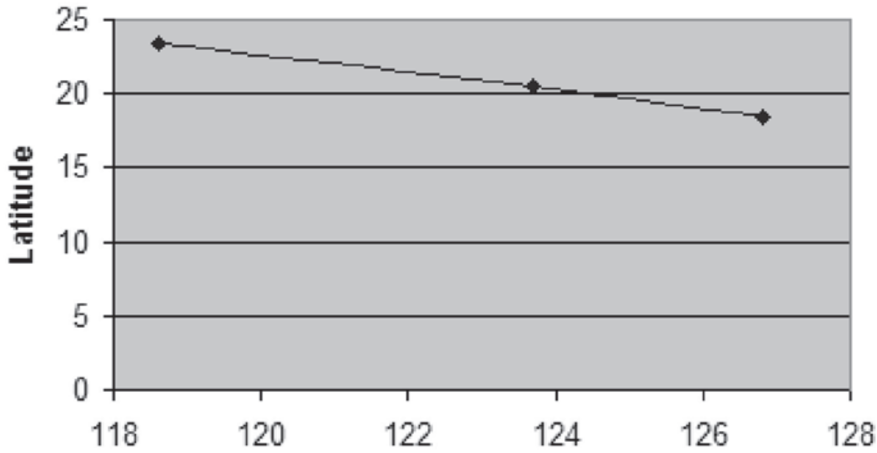

Figure 2. Track of 03w from 126.8 east between 4-6 June 1988 (Longitude).

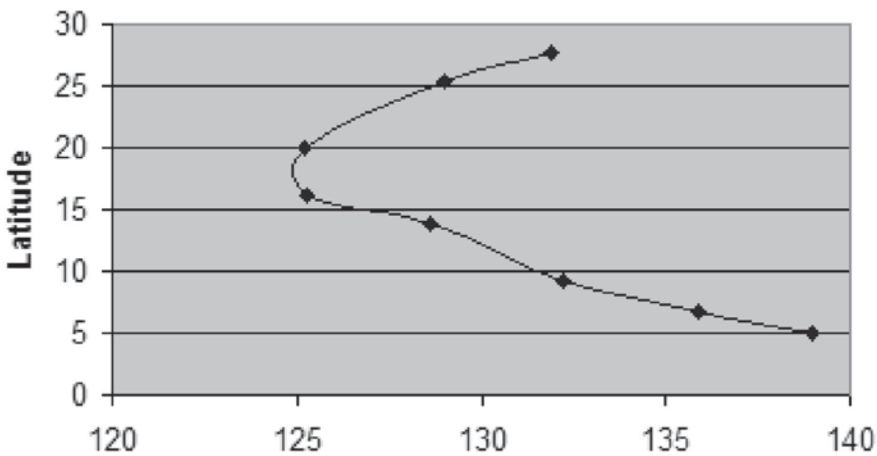

Figure 3. Track of 04w from 139.0 east between 18-24 June 1988 (Longitude).

Table 4. NWP systems crossed 30° north during All India Normal / Excess monsoon years.

Year	June	July	August	September	Total
1963	3	1	2	0	6
1964	0	2	3	1	6
1967	0	1	1	1	3
1971	0	1	3	2	6
1976	0	4	1	1	6
1977	0	0	1	1	2
1978	1	0	3	2	6
1980	0	0	0	2	2
1981	1	2	1	0	4
1983	0	0	2	1	3
1984	0	1	3	0	4
1985	1	0	6	0	7
1988	0	0	1	1	2
1989	1	1	2	2	6
1990	1	1	4	1	7
1991	0	1	3	4	8
1992	1	1	3	2	7
1993	0	3	1	2	6
1994	0	1	4	1	6
1995	0	1	1	2	4
1996	0	1	3	1	5
1997	2	1	3	1	7
1998	0	0	0	6	6
1999	0	2	5	3	10
2000	0	3	3	1	7
2001	0	0	1	2	3
2003	2	0	2	2	6
Total	13	28	62	42	145
A. M.	0.5	1.0	2.3	1.6	5.4

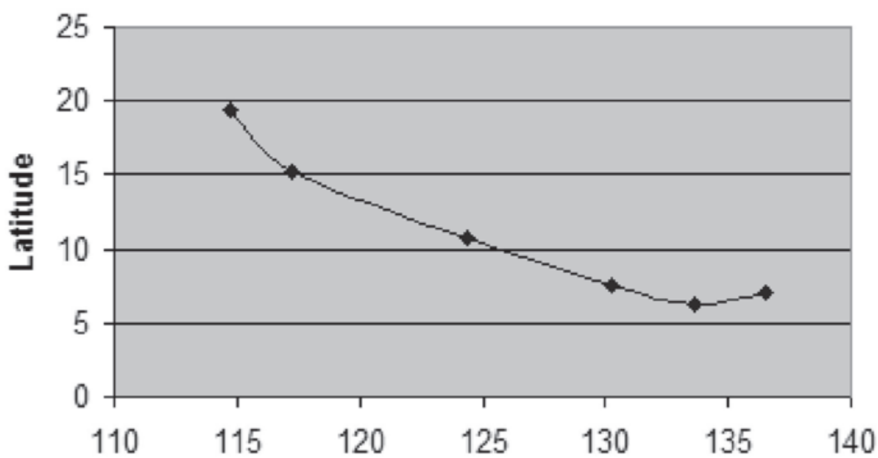

Figure 4. Track of 05w from 136.5 east between 24-29 June 1988 (Longitude).

Table 5. NWP systems crossed 30° north during All India Deficient monsoon years.

Year	June	July	August	September	Total
1965	2	0	2	3	7
1966	1	0	2	2	5
1968	0	1	2	1	4
1972	1	3	1	1	6
1974	1	2	4	1	8
1979	0	1	2	2	5
1982	0	0	3	2	5
1986	1	1	2	0	4
1987	0	4	3	3	10
2002	1	6	2	1	10
2004	2	2	2	2	8
Total	9	20	25	18	72
A.M.	0.8	1.8	2.3	1.6	6.5
B.F	13	28	62	42	145
Total	22	48	87	60	217
A.M	0.6	1.3	2.3	1.6	5.7

Positive impact of NWP systems on AIMR

When the NWP system reaches west of 140°E and follows westerly or northwesterly track, the monsoon system over India in general gets strengthen due to extension of east-west trough horizontally and vertically. As ISMR depends on many parameters, positive CC (+0.368) found between AIMR and number of systems reached west of 120°E confirms that NWP systems help ISMR. Out of 705 NWP systems, which were observed up to IDL during the study period, 551 systems (78 %) reached west of 140°E during summer monsoon. Out of 551 NWP systems which reached west of 140°E, 237 (43%) systems reached west of 120°E. On an average 6.7 systems reached west of 120°E during normal and 5.0 systems during deficient monsoon years respectively.

On 1st August 2006 an LPA formed over northwest Bay of West Bengal - Orissa coasts under the influence of an upper air cyclonic circulation extending up to mid tropospheric level over northwest Bay and neighbourhood. A tropical storm (TS) 07w (upgraded from TD) was centered on 1st August near 16.8°N/ 118.8°E at 0000 UTC. The LPA became well marked in the evening and concentrated into a MD near 20.5°E/ 87.5°E on 2nd at 0300 UTC. The TS 07w was located near 17.1°N/ 116.5°E at 0000 UTC on 2nd. East-west trough is seen at 850 hPa constant pressure chart (Figure 5) from 080°E to 120°E between 15°N and 25°N and is also observed up to 500 hPa. When NWP systems were located south of 25°N, 94% of the total monsoon LPA concentrated into depressions (32 out of 34) in the Bay. During 14 years period (1987, 1988, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1998, 1999, 2000, 2001 and 2002) 34 LPA formed in the Bay, when an NWP system was observed west of 120°E. Here again 94%, of total LPA (32 out of 34) had formed in the Bay when the NWP systems were located south of 25°N. On 20th July 2010 a tropical depression 04w was located near 15.3°N/118.1°E at 0000 UTC. It became TS at 0000 UTC on 21st and was centered near 18.3°N/113.0°E. An upper air cyclonic circulation developed over coastal Andhra Pradesh and neighborhood on 21st morning between 0.9 km and 5.8 km. In similar 9 other cases (1983, 1984, and 1992, 1993: 2, 1997, 1998, 2000 and 2001) upper air cyclonic circulation up to mid tropospheric level were observed along the east coast of India when an NWP system was located west of 120°E. Therefore the presence of an NWP system west of 120°E brightens the chance of formation of a MD / LPA / an upper air cyclonic circulation over the Bay of Bengal.

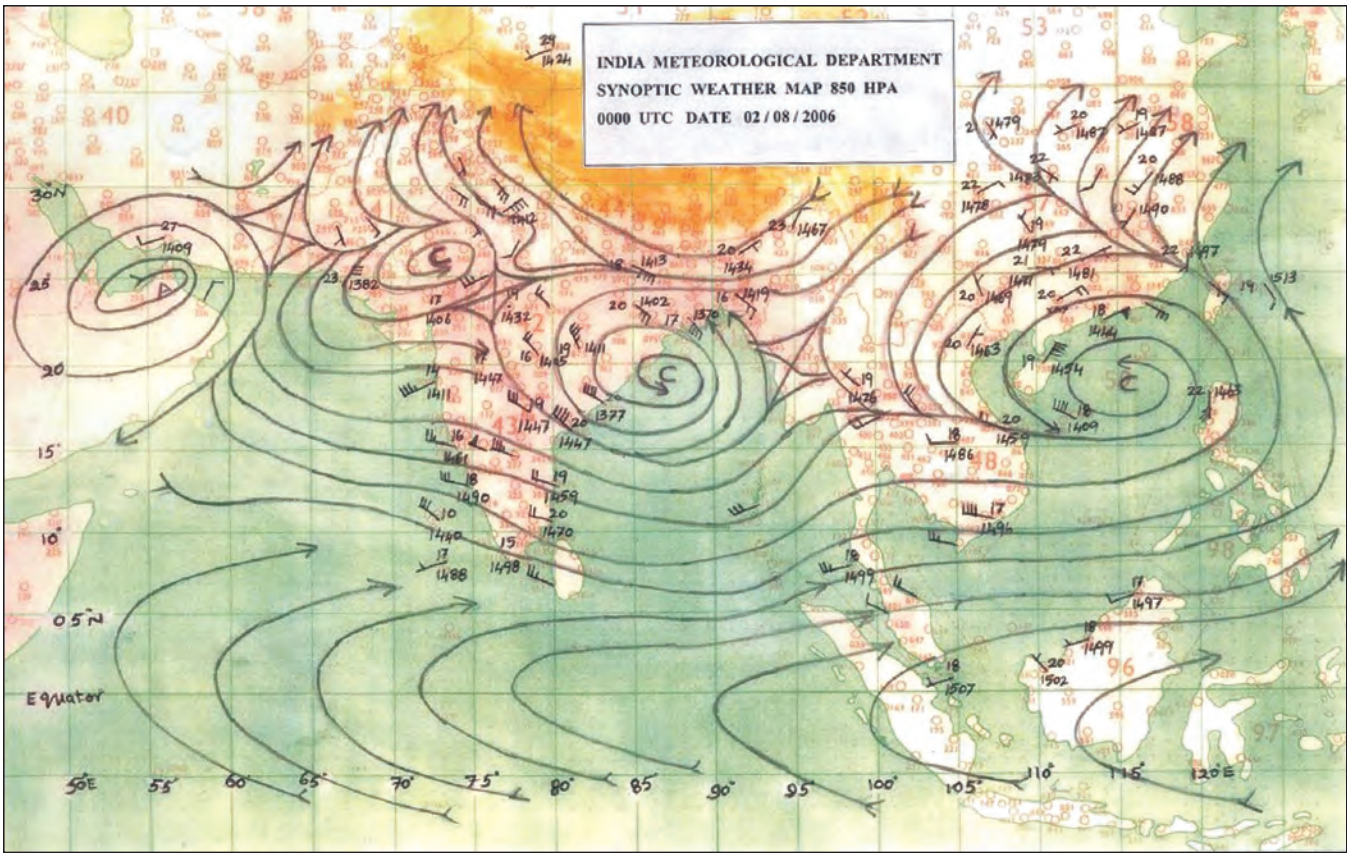

Figure 5. 850 hPa Synoptic weather chart of 2nd August 2006 at 0000 UTC.

Crossing of NWP systems north of 30°N and their negative impact on ISMR

During 1987, 1999 and 2002 south west monsoon season, 10 NWP systems crossed 30°N. During 2002, six NWP systems crossed 30°N in the month of July, which is highest in 38 years study period. The NWP system 08w which was located near 06.3°N/155.5°E on 1st July started recurving on 8th after reaching 25.2°N/132.5°E and crossed 30.0°N on 10th. Another system 09w was located near 15.3°N/133.1°E on 1st July, recurved after reaching 32.7°N/ 123.7°E on 5th. The 3rd system 10w, which was located near 11.3°N/ 160.3°E on 5th, recurved after reaching 27.2°N/ 127.6°E on14th. The only system 11w, which was located near 20.1°N/ 117.5°E on 8th, recurved throughout its period and crossed 30.0°N on 13th. The system 12w, which was located near 11.2°N/ 171.0°E on 14th, did not recurve and dissipated on 27th near 34.9°N/ 122.3°E. The 6th system 13w, which was located near 08.4°N/ 130.3°E on 17th, did not recurve and dissipated near 16.6°N/ 120.0°E on 21st. The last system 14w which was located near 23.9°N/143.7°E on 20th moved in south westerly direction till 24th (20.5°N/ 132.7°E) and recurved thereafter and crossed 30.0°N on 27th. Out of 6 systems which crossed 30.0°N during the month, one recurved after reaching 32.0°N, two each after reaching 25.0°N and 20.2°N respectively. So it is clear that out of seven NWP systems, which remained east of 120° E during July, only one system, did not appear to have influence on ISMR at all, because of its movement in north east direction from the very beginning. Therefore NWP systems did not cause deficient monsoon rainfall during July 2002. Indian summer monsoon mainly depends on Arabian Sea and Bay of Bengal branches of monsoon currents, which were weak during the year. In general, cross equatorial flow during 2002 was weaker than normal (5-10 knots) by 5 knots or less along the equator over Arabian Sea within 5° latitude of the equator during June to September. Over Bay of Bengal, the cross equatorial flow was less than normal (5-10 knots) by 5 knots or less since last week of June till August (Mausam 2003). On an average 5.5 systems crossed 30°north during normal and 6.5 systems during deficient monsoon years (August: 2.3). If an NWP system, which is centered west of 140°east, starts moving in northerly or northeasterly direction support of south China Sea branch of monsoon current to Indian summer monsoon ceases as ITCZ over the country gets disconnected with the ITCZ emanating from NWP system on account of its movement in opposite direction (cyclonic flow having westerly and easterly components along the trough up to the Bay branch and northerly (easterly) and westerly components onwards along the trough). As such Indian summer monsoon did not get support from a recurving NWP system.

AIMR and number of NWP systems crossing 30°north are negatively correlated (-0.428) but not so significantly to cause deficient monsoon. This is also in agreement with Raman (1955) observation that if there are unsettled conditions or a depression in the Bay, break monsoon can not be initiated by a typhoon or its remnant over the western Pacific moving to the north of 30°N. Also when an NWP system moves in northwesterly direction above 25°N, and crosses 30°N, monsoon rain area shrinks because of movement of monsoon trough northwards. But under these conditions Bihar, Sub- Himalayan West Bengal and other northeast states receive good amount of rainfall.

CONCLUSIONS

Effect of NWP system on ISMR is observed when it reaches west of 140°E. Intensity of clouds over the country is more marked along the ITCZ if there is an NWP system west of 140°E. When an NWP system reaches west of 120°E, MD forms over the Bay if there is an LPA over the Bay. Monsoon lows and upper air cyclonic circulations had also formed under such conditions. In 94% cases each, MD and LPA had formed over the Bay when the NWP systems were located south of 25°north. NWP systems, crossing 30°N, have got negative impact on ISMR but are not responsible for failure of south west monsoon. Excess cyclone genesis over NWP during summer monsoon is not the cause of monsoon failure. Cyclone genesis even in all weeks of June over NWP after onset of monsoon over Kerala does not affect ISMR. Even during excess monsoon year, cyclone genesis has taken place in all weeks of June after onset of monsoon over Kerala. NWP systems can not alter normal/ excess monsoon conditions into deficient monsoon conditions and vice versa.

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REFERENCES

Dash, S.K. & Mohanty, P.K., 1999. Variability of monsoon circulation feature and surface fields over Indian Ocean based on NCEP analysis, Vayu Mandal, 29, 1-4, 1

Joseph, P.V.,1990. Monsoon variability in relation to equatorial trough activity over Indian and west Pacific Oceans, Mausam, 41, 2, 293-294.

Joseph, P.V., Rajan, C.K. & Sooraj, K.P.,2001. Atmospheric conditions during and prior to monsoon onset over Kerala, TROPMET 2001, 176.

Mohanty, P.K. & Dash, S.K., 1994.Variability of surface fields in different branches of monsoon, Mausam, 46, 3, 313-321.

Rajeevan, M., 1993. "Inter- relationship between NWP typhoon activity and Indian summer monsoon on Inter-annual and Intra-seasonal time scales" Mausam, 44, 1, 109-110.

Raman, C.R.V., 1955. Current Science, 24, 219-220.

Ramanna, G.R., 1969. Indian J. Met. Hydrol. Geophys, 19, 148-150.

Weather in India, Mausam, 54, 3, 2003, 792.

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