Chapter VIII

General Summary and Conclusions

Chief features of the variability of the parameters of the hydrological wet season (HWS), onset and withdrawal of monsoon, wet and dry spells, soil water balance and effect of El Nino and La Nina over 11 major basins, 36 minor basins and the west coast drainage system are summarized below.

- Indus Major River Basin

Normal Hydrological wet season over the Indus basin starts around 25 June (±12 days) and ends around 9 September (±13 days) with the span of 77 days (±17). Total seasonal rainfall during the normal HWS is 505.6 mm with the surplus of 0.13 mm. During La Niña years the HWS starts ~7 days earlier (not significant), ends ~12 days late (significant at 5% level), the duration ~19 days longer (significant at 1% level) and rainfall amount 292 mm higher (significant at 0.1% level). The mean onset date of summer monsoon is 1 July (± 8.0 days) and the withdrawal date is 23 September (± 9.0 days). The Indus lies in the sub-region 19. Compared to the El Niño years, during La Niña years the onset of the monsoon is 4 days earlier and duration 4 days longer (both statistically not significant). During monsoon period, four wet spells occur, each of duration 8.2 days and rainfall intensity 10.3 mm/day, the duration of each of the intervening dry spell is 17.2 days and the RI 2.8 mm/day. The percentage contribution of wet spell total rainfall to the annual total is 47.3%. After meeting the needs of soil moisture storage, over the Indus basin average annual rainwater is 68.26 bcm (billion cubic metre or km$^3$); actual evapotranspiration 57.81 bcm and surplus rainwater is 10.46 bcm.

Chenab Minor Basin

The HWS starts on 29 May (±65 days), ends on 11 Sept (±25 days) and the duration of HWS is 106 days (±70). During a normal wet season rainfall is 593.4 mm excess rainfall is 0.3 mm available in the basin.

Beas and Satluj Minor Basins

HWS started around 7 June (±34 days) and ended around 19 Sept (±16 days) with the duration- of 105 days (±42) over Beas minor basin while the Starting date of HWS over Satluj basin is 30 June (±15 days), ending date 5 Sept (±17 days) and duration 68
days (± 21). During a normal wet season the total rainfall is 350.4 mm (surplus is 277.6 mm ) and 385.2 mm (surplus is 385.2 mm) respectively over the Beas and Satluj basins. Over both of the basins the mean onset date of summer monsoon is 1 July (± 8.0 days) and the withdrawal date is 23 September (± 9.0 days). During monsoon period, four wet spells occur, each of duration 8.2 days and rainfall intensity 10.3 mm/day, the duration of each of the intervening dry spell is 17.2 days and the RI 2.8 mm/day. The percentage contribution of wet spell total rainfall to the annual total is 47.3%.

- **GANGA MAJOR RIVER BASIN**

  The starting date of the HWS is 9 June (±9 days), ending date 28 Sept (±11 days) and the duration 113 days (± 15) with the normal wet season rainfall 859.9 mm and surplus rainfall 361.5 mm available in the basin. During La Niña years the HWS starts ~8 days earlier (significant at 5% level), ends ~13 days later (significant at 1% level), the duration ~20 days longer (significant at 1% level) and rainfall amount 231mm higher (significant at 0.1% level). The onset of summer monsoon varies from 13 June to 30 June from eastern to western Ganga basin with a standard deviation of 7 days. While the withdrawal date varies from 27 September to 10 October from western to eastern part of the basin with the deviation of 6 to 8 days. The basin is spread over 3 subregions (14, 16 and 17). Compared to the El Niño years, during La Niña years, over eastern part (subregion 14) the monsoon onset is 6 days earlier, withdrawal 6 days later and duration 12 days longer (statistically not significant). In the central part (subregion 16), the monsoon onset 2 days earlier, withdrawal 2 days later and duration 4 days longer (statistically not significant). Over western part (subregion 17), the onset is 5 days earlier, withdrawal is 4 days later and duration 9 days longer (significant at 5% level). In the eastern part of the basin, seven wet spells occur, each of duration 7.7 days and rainfall intensity 16.8 mm/day- the duration of each of the intervening dry spell is 11.3 days and the RI 4.5 mm/day. While for central part six wet spells occur, each of duration 7.1 days and rainfall intensity 16.8 mm/day the duration of each of the intervening dry spell is 10.5 days and the RI 3.4 mm/day. Over the western Ganga basin, five wet spells occur, each of duration 9.4 days and rainfall intensity 11.9 mm/day- the duration of each of the intervening dry spell is 12.0 days and the RI 2.6 mm/day. After meeting the needs of soil moisture storage, over the Ganga basin, average annual rainwater is 829.68 bcm; actual evapotranspiration 588.80 bcm and surplus rainwater is 241.13 bcm.
YAMUNA AND SIND MINOR BASINS

The starting date of the HWS over Yamuna basin is 25 June (±13 days), ending date- 14 Sept (±16 days) and the duration- 82 days (± 19). During a normal HWS, rainfall is 528.2 mm and surplus available is 179.2 mm. For Sind basin, the starting date is 22 June (±12 days), ending date is 16 Sept (±15 days) and the duration is 87 days (± 18). The total seasonal rainfall is 693.6 mm and excess rainfall is 319.4 mm. Over both basins, the summer monsoon starts on 30 June (±8) and ends on 27 September (±8). There are five wet spells occur, each of duration 9.4 days and rainfall intensity 11.9 mm/day the duration of each of the intervening dry spell is 12.0 days and the RI 2.6 mm/day.

RAMGANGA AND GOMATI MINOR BASINS

Over Ramganga basin HWS started around 8 June (±13 days) and ended around 24 Sept (±15 days) with the duration- 109 days (±19) while over Gomati, the Starting date of HWS is 19 June (±12 days), ending date 27 Sept (±15 days) and duration 100 days (±19). During a normal wet season the total rainfall is 1078.5 mm (surplus is 657.2 mm) and 760.6 mm (surplus is 447.5 mm) respectively over the Beas and Satluj basins. Over both of the basins, the mean onset date of summer monsoon is 1 July (±8.0 days) and the withdrawal date is 23 September (±9.0 days). During monsoon period, four wet spells occur, each of duration 8.2 days and rainfall intensity 10.3 mm/day the duration of each of the intervening dry spell is 17.2 days and the RI 2.8 mm/day. The percentage contribution of wet spell total rainfall to the annual total is 47.3%.

GHAGRA AND TONS MINOR BASINS

Over Ghagra basin, the starting date of the HWS is around 10 June (±12 days), ending date- 30 Sept (±14 days) and the duration- 113 days (±19). The seasonal rainfall is 933.5 mm and excess rainfall is 472.8 mm. Over Tons, the starting date is 18 June (±12 days), ending date is 28 Sept (±16 days) and the duration is of 103 days (±20). The wet season rainfall is 879.2 mm surplus rainfall is 444.3 mm available in the basin. Over both of the basins, the summer monsoon starts around 21 June (±7 days) and ends around 3 October (±6 days). During monsoon period, six wet spells occur, each of duration 7.1 days and rainfall intensity 16.8 mm/day, the duration of each of the intervening dry spell is 10.5 days and the RI 3.4 mm/day.
Chapter VIII

Summary and Conclusion

GANDAK, KOSI AND MAHANANDA MINOR BASINS

The Starting date of hydrological wet season over Gandak basin is 31 May (±15 days), ending date is 1 Oct (±15 days) and the duration is 124 days (± 23). Normal wet season rainfall is 994.5 mm and surplus rainfall is 485.3 mm. For Kosi basin, the starting date is 20 May (±19 days), ending date is 4 October (±17 days) and the duration is 138 days (± 27). The normal wet season rainfall is 1183.0 mm and excess rainfall is 590.9 mm. Over the Mahananda basin, the HWS starts around 25 April (±18 days), ends around 11 October (±13 days) and the duration is 170 days (± 23). The total seasonal rainfall during HWS is 1946.3 mm out of which 1315.4 mm is available as a surplus. Over all of three basins the onset of summer monsoon starts around 13 June (±6 days) and ends around 10 October ((±6 days). During monsoon period of all three basins, on an average seven wet spells occur, each of duration 7.7 days and rainfall intensity 16.8mm/day, the duration of each of the intervening dry spell is 11.3 days and the RI 4.5mm/day.

CHAMBAL AND BETWA MINOR BASINS

Over Chambal basin the HWs starts on 20 June (±11 days), ends on 3 Sept (±15 days) and the duration is 87 days (± 18). During a normal wet season rainfall is 635.0 mm and excess rainfall is 239.4 mm available in the basin. Over Betwa basin the HWS starts on 17 June (±10 days), ends on 22 Sept (±13 days) and the duration is 98 days (± 16). During a normal wet season rainfall is 856.4 mm and excess rainfall available is of 433.4 mm. The starting date of monsoon season over both of the basins varies from 21 June to 30 June and ending date from 27 September to 3 October. During monsoon period, five wet spells occur, each of duration 9.7 days and rainfall intensity 13.8 mm/day, the duration of each of the intervening dry spell is 11.9 days and the RI 3.2mm/day.

KEN AND SON MINOR BASINS

Over Ken basin the HWS starting date is 17 June (±11 days), ending date is 25 Sept (±17 days) and the duration is 101 days (± 19 days). The normal wet season rainfall is 948.6 mm and surplus rainfall is 533.3 mm. Over Son basin, starting date is 8 June (±10 days), ending date is 2 October (±12 days) and the duration is 117 days (± 17). The normal wet season rainfall is 1004.0 mm and excess rainfall is 516.2 mm. The onset date of southwest monsoon over both of the basins is 20 June (±7 days) and withdrawal date is 7 October (±6 days).
• **Brahmaputra Major River Basin**

The Hydrological wet season starts on 26 March (±13 days), ends on 20 October (±12 days) and the duration 209 days (± 17). During a normal wet season rainfall is 2304.1 mm and excess rainfall is 1528.0 mm. During La Niña years the HWS starts ~1 day later (not significant), ends ~12 days later (significant at 5% level), the duration ~11 days longer (not significant) and rainfall amount 315 mm higher (significant at 1% level). The summer monsoon onset occurs around 6 June (± 7 days) and ends around 15 October (± 5 days). The basin lies in the subregion 18. Compared to the El Niño years, during La Niña years, the onset is 8 days earlier (significant at 1% level) and duration 9 days longer (significant at 5% level). During monsoon period, seven wet spells occur, each of duration 7.5 days and rainfall intensity 18.2 mm/day, the duration of each of the intervening dry spell is 12.3 days and the RI 5.6 mm/day. After meeting the needs of soil moisture storage, over the Brahmaputra basin, average annual rainwater is 480.04 bcm; actual evapotranspiration 211.35 bcm and surplus rainwater is 268.90 bcm.

**Tista, Brahmaputra and Dhansiri Minor Basins**

The HWS of Tista started on 14 April (±19 days), ends on 15 October (±13 days) and the duration is 185 days (± 24 days). The normal wet season rainfall is 3094.4 mm and surplus rainfall is 2441.5 mm available in the basin. For Brahmaputra minor basin the HWS starts on 27 March (±14 days), ends on 18 October (±13 days) and the duration is 206 days (± 19). The normal wet season rainfall is 2076.7 mm and excess rainfall is 1310.3 mm available in the basin. In Dhansiri basin the starting date of the HWS is on 4 April (±25 days), ending date is 18 October (±16) and the duration is 198 days (± 30). The total seasonal rainfall is 1681.6 mm excess rainfall is 1091.6 mm. During monsoon period, seven wet spells occur, each of duration 7.5 days and rainfall intensity 18.2 mm/day the duration of each of the intervening dry spell is 12.3 days and the RI 5.6 mm/day.

• **Godavari Major River Basin**

The starting date of HWS is 9 June (±7 days), ending date is 4 October (±16 days) and the duration is 118 days (± 19 days). The HWS rainfall is 854.7 mm and excess rainfall 368.6 mm is available in the basin. During La Niña years the HWS starts ~5 days earlier (significant at 10% level), ends ~8 days later (not significant), the duration ~13 days longer (not significant) and rainfall amount 222 mm higher (significant at 1% level). The onset of summer monsoon starts around 16 June (±6 days) and withdrawal occurs between
8-12 October. The basin is spread over subregions 9 and 10. Compared to the El Niño years, during La Niña years, over western part of the basin monsoon onset is 5 days earlier (significant at 55 level), withdrawal 9 days later (significant at 0.1% level) and duration 14 days longer (significant at 0.1% level). While over eastern part of the basin, (sub-region 10) the monsoon onset is 5 days earlier (not significant), withdrawal 7 days later (significant at 0.1% level) and duration 12 days longer (significant at 1% level). During monsoon period, six wet spells occur, each of duration 7.7 days and rainfall intensity 14.8mm/day the duration of each of the intervening dry spell is 12.2 days and the RI 3.4mm/day. After meeting the needs of soil moisture storage, over the Godvari basin, average annual rainwater is 356.83 bcm; actual evapotranspiration 236.77 bcm and surplus rainwater is 120.05 bcm.

**WAINGANGA AND INDRAVATI MINOR BASINS**

The HWS starts over Wainganga on 9 June (±8 days), ends around 2 October (±15 days) and the duration is 116 days (± 17). During a normal wet season rainfall is 1051.9 mm and excess rainfall of 604.2 mm is available in the basin. While over Indravati the starting date of HWS is around 29 May (±20 days), ending date is 12 October (±18 days) and the duration is 137 days (± 28). The HWS rainfall is 1272.3 mm and surplus rainfall of 792.8 mm is available in the basin. The onset of monsoon over both of the basins is around 16 June (±6 days) and withdrawal is around 12 Oct (±6 days). During monsoon period, six wet spells occur, each of duration 6.9 days and rainfall intensity 16.2mm/day the duration of each of the intervening dry spell is 11.1 days and the RI 4.0mm/day.

**WARDHA, PENGANGA AND GODAVARI MINOR BASINS**

For Wardha basin the HWS starting date is 9 June (±8 days), ending date is 29 Sept (±18 days) and the duration is 113 days (± 20). The normal wet season rainfall is 840.1 mm and excess rainfall is 339.0 mm. For Penganga basin the HWS starting date is 10 June (±10 days), ending date is 28 Sept (±18 days) and the duration is 111 days (± 21). The normal wet season rainfall is 870.9 mm and excess rainfall is 389.4 mm. For Godavari minor basin the HWS starts on 11 June (±9 days), ends on 2 October (±15 days) and the duration is 115 days (± 18). The normal wet season rainfall is 681.5 mm and surplus rainfall is 167.8 mm. For all the three basins the onset of monsoon is 15 June (±6 days) and withdrawal is 8 Oct (±7 days). During monsoon period, six wet spells occur, each of
duration 8.6 days and rainfall intensity 13.5 mm/day, the duration of each of the intervening dry spell is 13.3 days and the RI 2.9 mm/day.

- **Krishna Major River Basin**

  The HWS starting date is 5 June (±14 days), ending date is October (±17 days) and the duration is 137 days (± 24). The normal wet season rainfall is 610.4 mm and excess rainfall of 137 mm available in the basin. During La Niña years, the HWS rainfall amount is 137 mm higher (significant at 1% level). The southwest monsoon starts around 11 June (±6 days) and ends around 14 October (±6 days). The basin is spread over three subregions (5, 6 and 7). Compared to the El Niño years, during La Niña years, over western part the monsoon starts 5 days earlier (not significant), withdrawal 11 days later (significant at 0.1% level) and duration 16 days longer (significant at 0.1% level). Over central part, the monsoon starts four days earlier (not significant), ends 11 days later (significant at 0.1% level), and duration 15 days longer (significant at 0.1% level). Over eastern part, the monsoon starts 6 days earlier (significant at 5%), ends 12 days later (significant at 1% level) and duration 18 days longer (significant at 0.1% level). During monsoon period, five wet spells occur, each of duration 8.7 days and rainfall intensity 14.3.6 mm/day the duration of each of the intervening dry spell is 11.4 days and the RI 3.2 mm/day. After meeting the needs of soil moisture storage, over the Krishna basin, average annual rainwater is 217.34 bcm; actual evapotranspiration 160.23 bcm and surplus rainwater is 57.09 bcm.

**Krishna Minor Basin**

The starting date of HWS 6 June (±14 days), ending date is 21 October (±17 days) and the duration is 138 days (±24). During a normal wet season rainfall is 686.0 mm and potential excess rainfall of 129 mm is available in the basin. The southwest monsoon starts around 11 June (±6 days) and ends around 14 October (±6 days). During monsoon period, five wet spells occur, each of duration 8.7 days and rainfall intensity 14.3.6 mm/day the duration of each of the intervening dry spell is 11.4 days and the RI 3.2 mm/day.

**Bhima Minor Basin**

The starting date of HWS is 9 June (±16 days), ending date is 28 Sept (±33 days) and the duration is 112 days (±36). During a normal wet season rainfall is 504.8 mm and deficit rainfall is 2.8 mm. The mean onset date of monsoon season is 11 June (±6 days)
and withdrawal date is 14 October (±6 days). During monsoon period, five wet spells occur, each of duration 7.9 days and rainfall intensity 8.9mm/day, the duration of each of the intervening dry spell is 14.6 days and the RI 1.3mm/day.

**Tunghabhadra Minor Basin**

The normal HWS starts on 31 May (±21 days), ends on 17 October (±19 days) and the duration is 141 days (± 31). During a normal wet season rainfall is 534.4 mm and rainfall of 75.6 mm is present in the basin. The monsoon starts around 5 to 11 June and withdraws around 14 to 19 October. During monsoon period, five wet spells occur, each of duration 9.7 days and rainfall intensity 22.9mm/day, the duration of each of the intervening dry spell is 7.7 days and the RI 1.5mm/day.

**Sabarmati and Mahi Major River Basin**

For Sabarmati basin the HWS starts on 22 June (±14 days), and ends on 7 Sept (±18 days). The duration is 78 days (± 23). During a normal wet season rainfall is 519.8 mm and potential excess rainfall is 177.3 mm. During La Niña years the HWS starts ~7 day earlier (not significant), ends ~6 days later (not significant), the duration ~12 days longer (not significant) and rainfall amount 107mm higher (significant at 10% level). While for Mahi basin the starting date is 18 June (±12 days), ending date is 15 Sept (±17 days) and the duration is 90 days (± 21). During a normal wet season rainfall is 688.6 mm surplus is 307.8 mm available in the basin. During La Niña years, the HWS starts ~7 day earlier (not significant), ends ~18days later (significant at 5% level), the duration ~21 days longer (significant at 1% level) and rainfall amount 174mm higher (significant at 0.1% level). For both of the basins the monsoon onset is around 23 June (±9 days) and withdrawal is around 28 September (±6 days). Compared to the El Niño years, during La Niña years the monsoon onset is 5 days earlier, withdrawal 10 days later (significant at 1% level) and duration 15 days longer (significant at 5% level). During monsoon period, four wet spells occur, each of duration 8.8 days and rainfall intensity 13.5mm/day, the duration of each of the intervening dry spell is 17.2 days and the RI 1.5mm/day. After meeting the needs of soil moisture storage, over the Sabarmati basin, average annual rainwater is 31.56 bcm; actual evapotranspiration 22.39 bcm and surplus rainwater is 9.16 bcm.
• **NARMADA AND TAPI MAJOR RIVER BASIN**

The starting date of HWS for Narmada basin is 12 June (±8 days), ending date is 25 Sept (±15 days) and the duration is 106 days (±17). During a normal wet season rainfall is 925.0 mm and excess rainfall of 515.3 mm is available in the basin. During La Niña years the HWS starts ~7 day earlier (significant at 5% level), ends ~18 days later (significant at 1% level), the duration ~25 days longer (significant at 0.1% level) and rainfall amount 253 mm higher (significant at 5% level). While for Tapi basin, the starting date of HWS is 11 June (±7 days), ending date is 24 Sept (±18 days) and the duration is 106 days (±20). During a normal wet season rainfall is 700.3 mm and excess rainfall 249.9 mm. During La Niña years, the HWS starts ~3 days earlier (not significant), ends ~20 days later (not significant), the duration ~24 days longer (significant at 0.1% level) and rainfall amount 190 mm higher (significant at 5% level). For both basins the southwest monsoon onset occurs around 21 June (±8 days) and withdraws around 3 October (±6 days). Compared to the El Niño years, during La Niña years the monsoon onset is 4 days earlier, withdrawal 6 days later and duration 9 days longer (significant at 5% level). During monsoon period, five wet spells occur, each of duration 10.1 days and rainfall intensity 15.8 mm/day, the duration of each of the intervening dry spell is 11.8 days and the RI 3.8 mm/day. After meeting the needs of soil moisture storage, over the Narmada basin, average annual rainwater is 114.78 bcm (billion cubic metre or km$^3$); actual evapotranspiration 68.76 bcm and surplus rainwater is 46.05 bcm. While over the Tapi basin, average annual rainwater is 58.74 bcm; actual evapotranspiration 44.62 bcm and surplus rainwater is 14.15 bcm.

• **MAHANADI MAJOR RIVER BASIN**

The starting date of HWS is 4 June (±10 days), ending date is 11 October (±15 days) and the duration is 130 days (±19). During a normal wet season rainfall is 1193.0 mm and excess rainfall is 674.5 mm. During La Niña years, the HWS starts ~6 days earlier (not significant), ends ~13 days later (significant at 5% level), the duration ~19 days longer (significant at 1% level) and rainfall amount 183 mm higher (not significant). The summer monsoon onset occurs on 16 June (±6 days) and withdraws from basin on 12 October (±6 days). Compared to the El Niño years, during La Niña years the monsoon onset is 5 days earlier, withdrawal 7 days later (significant at 0.1% level) and duration 12 days longer (significant at 1% level). During monsoon period, six wet spells occur, each of duration
6.9 days and rainfall intensity 16.2 mm/day, the duration of each of the intervening dry spell is 11.1 days and the RI 4.0 mm/day. After meeting the needs of soil moisture storage, over the Mahanadi basin, average annual rainwater is 189.54 bcm; actual evapotranspiration 119.38 bcm and surplus rainwater is 70.09 bcm.

- **CAUVERY MAJOR RIVER BASIN**

  The starting date of HWS is 4 May (±15 days), ending date is 11 November (±18 days) and the duration is 192 days (±20). During a normal wet season rainfall is 1064.5 mm and excess rainfall of 290.7 mm is available in the basin. During La Niña years, the HWS starts ~13 days earlier (significant at 1% level), ends ~18 days earlier (significant at 1% level), the duration ~5 days shorter (not significant) and rainfall amount 78 mm higher (not significant). The monsoon onset occurs around 4 June (±6 days) and withdraws around 18 Oct (±6 days). Compared to the El Niño years, during La Niña years the monsoon onset is 7 days earlier (significant at 5% level), withdrawal 11 days later (significant at 5% level) and duration 18 days longer (significant at 5% level). During monsoon period, six wet spells occur, each of duration 9.1 days and rainfall intensity 7.9 mm/day, the duration of each of the intervening dry spell is 17.3 days and the RI 0.9 mm/day. After meeting the needs of soil moisture storage, over the Cauvery basin, average annual rainwater is 78.05 bcm; actual evapotranspiration 53.97 bcm and surplus rainwater is 24.22 bcm.

- **INDEPENDENT MINOR BASINS**

  **LUNI BASIN**

  The starting date of HWS is 3 July (±14 days), ending date is 31 August (±19 days) and the duration is 60 days (±24). In comparison to other basins it experiences shortest duration of wet season. During a normal wet season rainfall is 402.4 mm and excess rainfall of 132.0 mm available is in the basin. The normal onset of monsoon is 8 July (±8 days) and withdrawal is 19 September (±8 days). During monsoon period, three wet spells occur, each of duration 7.7 days and rainfall intensity 9.2 mm/day, the duration of each of the intervening dry spell is 19.0 days and the RI 0.6 mm/day. After meeting the needs of soil moisture storage, over the Luni basin, average annual rainwater is 36.08 bcm; actual evapotranspiration 28.04 bcm and surplus rainwater is 8.03 bcm.


**SURMA BASIN**

The HWS starts on 16 March (±18 days), ends on 25 October (±14 days) and the duration is 225 days (± 21). Compared to other basins this basin experiences longest duration of wet season. During a normal wet season rainfall is 2314.0 mm and excess rainfall is 1595.2 mm available in the basin. The monsoon onset occurs on 6 June (±6 days) and withdraws on 15 October (±5 days). During monsoon period, seven wet spells occur, each of duration 7.5 days and rainfall intensity 18.2mm/day, the duration of each of the intervening dry spell is 12.3 days and the RI 5.6mm/day. After meeting the needs of soil moisture storage, over the Surma basin, average annual rainwater is 189.41 bcm; actual evapotranspiration 73.06 bcm and surplus rainwater is 116.36 bcm.

**KASAI, DAMODAR, SUVERNAREKHA AND BRAHMANI BASINS**

For Kasai basin the HWS starting date is 12 May (±22 days), ending date is 12 October (±16 days) and the duration is 154 days (± 26 days). A normal wet season rainfall is 1213.6 mm and surplus rainfall is 555.5 mm. For Damodar basin the HWS starting date is 4 May (±22 days), ending date is 14 October (±14 days) and the duration is 164 days (± 26). A normal wet season rainfall is 1271.5 mm mm and surplus rainfall is 579.5 mm. Over Suvernarekha basin the HWS starting date is 12 May (±24 days), ending date is 16 October (±15 days) and the duration is 158 days (± 26). A normal wet season rainfall is 1275.0 mm and surplus rainfall is 633.5 mm. For Brahmani basin the HWS starting date is 21 May (±18 days), ending date is 11 October (±16 days) and the duration is 144 days (± 25). A normal wet season rainfall is 1209.3 mm and surplus rainfall is 614.2 mm. For all four basins the summer monsoon onset occurs around 13 June (±6 days) and withdraws around 10 October (±6 days). During monsoon period, seven wet spells occur, each of duration 7.7 days and rainfall intensity 16.8mm/day, the duration of each of the intervening dry spell is 11.3 days and the RI 4.5mm/day. After meeting the needs of soil moisture storage, over the Kasai, Damodar, Suvernarekha and Brahmani basins, average annual rainwater is 58.09, 94.78, 54.62, 73.22 bcm respectively; actual evapotranspiration 35.18, 65.76, 37.97, 48.14 bcm and surplus rainwater is 18.02, 29.05, 16.66, 25.07 bcm respectively.

**PENNAR AND PALAR BASINS**

For Pennar basin the starting date of HWS is 21 July (±43 days), ending date is 24 November (±21 days) and the duration is 127 days (± 48). During a normal wet season
rainfall is 620.1 mm and deficit rainfall of 339 mm is available in the basin. Over Palar basin starting date is 3 July (±32 days), ending date is 12 December (±21 days) and the duration is 163 days (±39). A normal wet season rainfall is 944.9 mm and excess rainfall is 57.7 mm. Over both of the basins the monsoon onset occurs on 6 June (±7 days) and withdraws from basin on 17 October (±6 days). During monsoon period, six wet spells occur, each of duration 8.9 days and rainfall intensity 8.2 mm/day, the duration of each of the intervening dry spell is 16.9 days and the RI 1.1 mm/day. After meeting the needs of soil moisture storage, over the Pennar and Palar basins, average annual rainwater is 85.05 and 35.55 bcm respectively; actual evapotranspiration 58.91 and 25.88 bcm and surplus rainwater is 26.19 and 9.74 bcm respectively.

**VAIGAI BASIN**

The starting date of HWS is 14 August (±50 days), ending date is 9 December (±21 days) and the duration is 118 days (±54). A normal wet season rainfall is 763.5 mm and excess rainfall of 49.2 mm is available in the basin. The mean onset dates of monsoon season are 2 June (±7 days) and mean withdrawal date is 19 October (±6 days). During monsoon period, five wet spells occur, each of duration 9.4 days and rainfall intensity 7.6 mm/day, the duration of each of the intervening dry spell is 17.8 days and the RI 0.8 mm/day. After meeting the needs of soil moisture storage, over the Vaigai basin, average annual rainwater is 17.96 bcm; actual evapotranspiration 13.58 bcm and surplus rainwater is 4.42 bcm.

**WEST COAST DRAINAGE SYSTEM:**

The starting date of HWS is 30 April (±16), ending date is 11 November (±15) and the duration is 196 days (±20). During La Niña years, the HWS starts ~15 days earlier (significant at 5% level), ends ~18 days earlier (significant at 1% level), the duration ~3 days shorter (not significant) and rainfall amount 203 mm higher (significant at 10% level). The onset date of the monsoon varies from 1 June to 13 June and withdrawal date from 19 October to 7 October as moves from southern to northern West Coast. The hilly basin is spread over four subregions (1, 3, 5 and 8). Compared to the El Niño years, during La Niña years, over extreme south (subregion 1) the monsoon onset is 6 days earlier (significant at 5% level), withdrawal 7 days later and duration 13 days longer (significant at 5%). Over the southern central basin (subregion 3), the onset is 5 days earlier, withdrawal 9 days later (significant at 1% level) and duration 14 days longer (significant at
1% level). Over the northern central basin (subregion 5), the onset is 5 days earlier, withdrawal 11 days later (significant at 0.1% level) and duration 16 days longer (significant at 0.1% level). Over the northern part of the basin (subregion 8) the onset is 3 days earlier, withdrawal 8 days later (significant at 1% level) and duration 11 days longer (significant at 1% level). During the wet season, five wet spells occur, each with duration 10.4 days and rainfall intensity of 30.8mm/day, the duration of each dry spell is 13.8 days and the RI 7.2mm/day. During a normal wet season rainfall is 2292.9 mm and potential evapotranspiration 764.7 mm which shows excess rainfall of 1528.2 mm available in the basin system.

It may be noted that the parameters of the main monsoon wet spell (MMWS) over the entire country are significantly adversely affected by the JJAS Niño 3.4 SST. During the La Niña years, the MMWS starts ~17 days earlier (significant at 5% level), ends ~12 days later (not significant) and duration ~28 days longer (significant at 5% level) compared to the El Niño years. Further, the mean MMWS rainfall during the La Niña years is higher by 26.7% (633.3 mm; significant at 5% level) and the rainwater more by 30% (550.1 mm) compared to the El Niño years. The difference in starting date, duration, rainfall amount, rainfall intensity and contribution to annual rainwater is significant at 5% level.

**Concluding Remark**

We earnestly feel that this study provides ample vital information for planning and management of agricultural and water resources activities to get relatively stable food grain production, hydro-power generation and drinking, industrial and irrigation water supply under variable rainfall/climatic conditions. Further, we envision that this will set the stage to generate requisite information on rainfall characteristics for planning and management of agriculture, water resources, ecosystem, hydrology, forestry, fisheries etc. under changing climate.

During the MMWS period, ~26% area of the country receives rainfall each day. The area of convergence and rainfall wanders all around under the influence of steering monsoon current. An ambitious future plan is to develop a numerical model for the determination of location, areal extent and intensity of rainfall occurrences by incorporating intra-seasonal spatial troposphere temperature-circulation variability over
global tropics, atmospheric baroclinicity, monsoon variability and regional convergence processes across the country.

**FUTURE OUTLOOK FOR 50 TO 200 YEARS:**

The surface air temperature is expected to be about 15°C (±0.5°C), and the summer monsoon rainfall over India 900 mm (±45mm). In order to cope up variability of the monsoon associated with the global climate change, we have to develop science, technology and skill to capture 1500 billion cubic metres (15x10^14 litres) of surplus rainwater annually available. On the other hand, this will drastically reduce the flood-related damages of life, economy and environment and on the other; it will make the efficiency and production of water related sectors independent of long range climate prediction.