MAUSAM, **55**, 3 (July 2004), 515-548

# Weather in India

# MONSOON SEASON (June to September 2003)†

## 1. Introduction

The normal rainfall during the current southwest monsoon season had been a welcome relief, as it came in the wake of a deficient monsoon. Also, the rainfall was well distributed both in space and time. Unlike the last year of large rainfall deficiency in July, the July rainfall this year was bountiful. Most parts of the country, especially those regions, which experienced severe drought conditions last year, also received good rainfall this time. The rainfall was *excess** in 7, *normal* in 26 and *deficient* in 3 meteorological Sub-divisions. Southwest monsoon set in over Kerala on 8 June with a delay of one week. Onset took place over northeast India 3 days prior to this, *i.e*. on 5 June. Monsoon current hitting the mainland over northeast India, earlier than that over the southern tip, had occurred previously, though not often *viz*. in years 2000, 1998, 1996, 1995, 1972, etc. The monsoon current reached south Andaman Sea by 16 May, prior to the normal date, in association with the formation of a very severe cyclonic storm over the Bay. The unusual and prolonged trajectory of the system, might have caused the delay in the further progress of the monsoon current. In addition, the changed flow pattern due to the cyclonic storm caused prolonged severe heat wave conditions over many parts of the country althrough the first fortnight of June, especially, over coastal Andhra Pradesh, Orissa and northern parts of Tamil Nadu. Though the withdrawal started on a delayed mode (about 2 weeks delay), all subsequent withdrawals took place in near normal dates. The number of monsoon depressions formed was quite less than normal, this year as well. Out of the 14 low pressure areas formed during the season only two concentrated into depressions.

## 2. Characteristic features of southwest monsoon 2003

2.1. Total seasonal monsoon rainfall over the country as a whole was 102% of its long period average, thus it has been a normal monsoon year.

2.2. Southwest monsoon set in over Kerala on 8 June with a delay of one week. Onset took place over NE India 3 days prior to this, *i.e.* on 5 June. No intense low pressure systems were present as onset vortex, other than an off-shore trough present along west coast.

2.3. Southwest monsoon covered the entire country on 5 July, 10 days prior to the normal date.

2.4. SW monsoon withdrew from parts of west Rajasthan and Punjab on 17 September with a delay of about 2 weeks. It withdrew from the entire country by 15 October which coincided with the normal date of withdrawal of SW monsoon.

2.5. Only two depressions formed during the season, both formed over the Bay of Bengal. The first one, a deep depression during 25–28 July and the second, a depression during 27–28 August. June and September were devoid of any depressions.

2.6. Rainfall during the monsoon 2003 was *excess* in 7 and *normal* in 26 meteorological sub-divisions. Rainfall activity was very good during the months of June (31-E/N) and July (30-E/N), though August (26-E/N) and September (14-E/N) were a little subdued.

2.7. Rainfall activity over peninsular India was quite subdued in the initial fortnight and was rather good in the second one. Thenceforth it remained good except over Karnataka and Kerala until week ending on 20 August.

2.8. Monsoon trough got established on 5 July and Tibetan anticyclone on 15 June. Off-shore trough along different parts of the west coast (surface and lower levels) persisted on most of the days from 6 June to 15 September. Also it was quite active during the first half of the season.

2.9. Cross equatorial flow was quite normal in general, during the entire season over the Arabian Sea and Bay of Bengal except during second half of September, when it was weaker than normal.

2.10. Northeast monsoon rains commenced over Tamil Nadu, Kerala and adjoining areas of Karnataka and Andhra Pradesh on 19 October 2003, around the normal date *i.e.*, 20 October. Also, this time there had been a clear-cut demarcation between the cessation of southwest monsoon rainfall and commencement of northeast monsoon rains as there was a gap of 4 days between the two.

* Definition of words in *italics* are given in Appendix

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## 3. Features of monsoon

### 3.1. *Advance of southwest monsoon*

By 27 June, the monsoon had covered most parts of the country and the entire country was covered by 5 July, 10 days prior to the normal date.

Advance was quite rapid over the western half of the country owing to the strong Arabian Sea branch of monsoon current and thus it advanced as far as upto south Rajasthan by 19 June, whereas the advance over the other half had been a bit slow, with a few spells of stagnation in the monsoon current, the longest being that of 7 – 18 June over North Bay and Sub Himalayan West Bengal & Sikkim. Fig. 1 gives the isochrones of advance.

### 3.2. *Weekly rainfall distribution*

#### 3.2.1. *Week by week rainfall*

Meteorological sub-divisionwise weekly rainfall departures (percentage departure from normal rainfall) during the southwest monsoon season comprising of 18 weeks (29 May to 1 October) are given in Fig. 2(a).

**Datewise onset of southwest monsoon 2003 over different areas**

| Date | Regions covered | Remarks |
|---|---|---|
| 16 May | South Andaman Sea and parts of southeast Bay | Advanced in association with the very severe cyclonic storm over the Bay of Bengal |
| 31 May | Parts of Maldives-Comorin areas, south Bay of Bengal and of east-central and entire north Andaman Sea | With a delay of about 10 days, caused due to the unusual trajectory of cyclonic storm |
| 3 Jun | Some more parts of east-central Bay | 8 days delay |
| 5 Jun | Some parts of south Arabian Sea, some more parts of south Bay and of east-central Bay, parts of northeast Bay and northeast India (most parts of Nagaland-Manipur-Mizoram-Tripura, Arunachal Pradesh and some parts of Assam & Meghalaya) | 4 days delay in most of the regions |
| 7 Jun | Some more parts of east-central Bay, entire northeast Bay, Assam & Meghalaya and in some parts of Sub-Himalayan West Bengal & Sikkim | 4 days delay in the oceanic parts, but in time over the land area |
| 8 Jun | Entire south Arabian Sea, most parts of Kerala, parts of Tamil Nadu and some more parts of south and central Bay. | 7 days delay |
| 10 Jun | Parts of central Arabian Sea, coastal & south interior Karnataka and some more parts of Tamil Nadu | Delay of 5 to 9 days |
| 11 Jun | Some more parts of central Arabian Sea, entire coastal Karnataka, some parts of Konkan & Goa, south interior Karnataka and of Tamil Nadu | Delay of 6 to 10 days |
| 15 Jun | Some more parts of central Arabian Sea and Konkan & Goa, most parts of Karnataka state, entire Tamil Nadu and Rayalaseema, most parts of Telangana, parts of coastal Andhra Pradesh, some more parts of west central Bay and some parts of northwest Bay. | 10 days delay |
| 16 Jun | More parts of central Arabian Sea, entire Konkan & Goa, most parts of Madhya Maharashtra and Marathwada and some more parts of Telangana | 5 days delay |
| 17 Jun | Some parts of north Arabian Sea, Saurashtra & Kutch, Gujarat Region and some more parts of Madhya Maharashtra | 3 to 4 days delay |
| 18 Jun | Some more parts of north Arabian Sea, Saurashtra & Kutch and Gujarat Region, some parts of Chattisgarh, entire coastal Andhra Pradesh, central & north Bay, some parts of Orissa and Jharkhand, most parts of Gangetic West Bengal and some parts of Sub-Himalayan West Bengal & Sikkim | 3 to 4 days delay in the west half and more than 12 days delay in the eastern parts |
| 19 Jun | Entire Arabian Sea, Gujarat State, parts of Rajasthan, entire Madhya Maharashtra and Marathwada, parts of west Madhya Pradesh and Vidarbha, entire Telangana, some more parts of Chattisgarh and Jharkhand, some parts of Bihar and entire West Bengal & Sikkim | 11 days ahead in southern parts of Rajasthan, 9 to 10 days delay over central and east India |
| 20 Jun | Some more parts of Orissa and Chattisgarh | 10 days delay |
| 23 Jun | Some more parts of west Madhya Pradesh, some parts of east Madhya Pradesh, entire Vidarbha, Chattisgarh, Orissa, Jharkhand, Bihar and some parts of east Uttar Pradesh. | 7 days delay |
| 24 Jun | Some more parts of east Rajasthan, Madhya Pradesh and east Uttar Pradesh | 9 days delay |
| 25 Jun | Some more parts of east Rajasthan, entire Madhya Pradesh, some more parts of east Uttar Pradesh, some parts of west Uttar Pradesh and most parts of Uttaranchal | 1 day delay |
| 26 Jun | Entire east Uttar Pradesh | Normal |
| 27 Jun | Rest Uttaranchal, entire Himachal Pradesh, Jammu & Kashmir and northern parts of Punjab | Normal |
| 5 Jul | Rest west Uttar Pradesh, Haryana, Punjab and Rajasthan and thus the entire country | 10 days ahead of the normal date in covering the entire country |

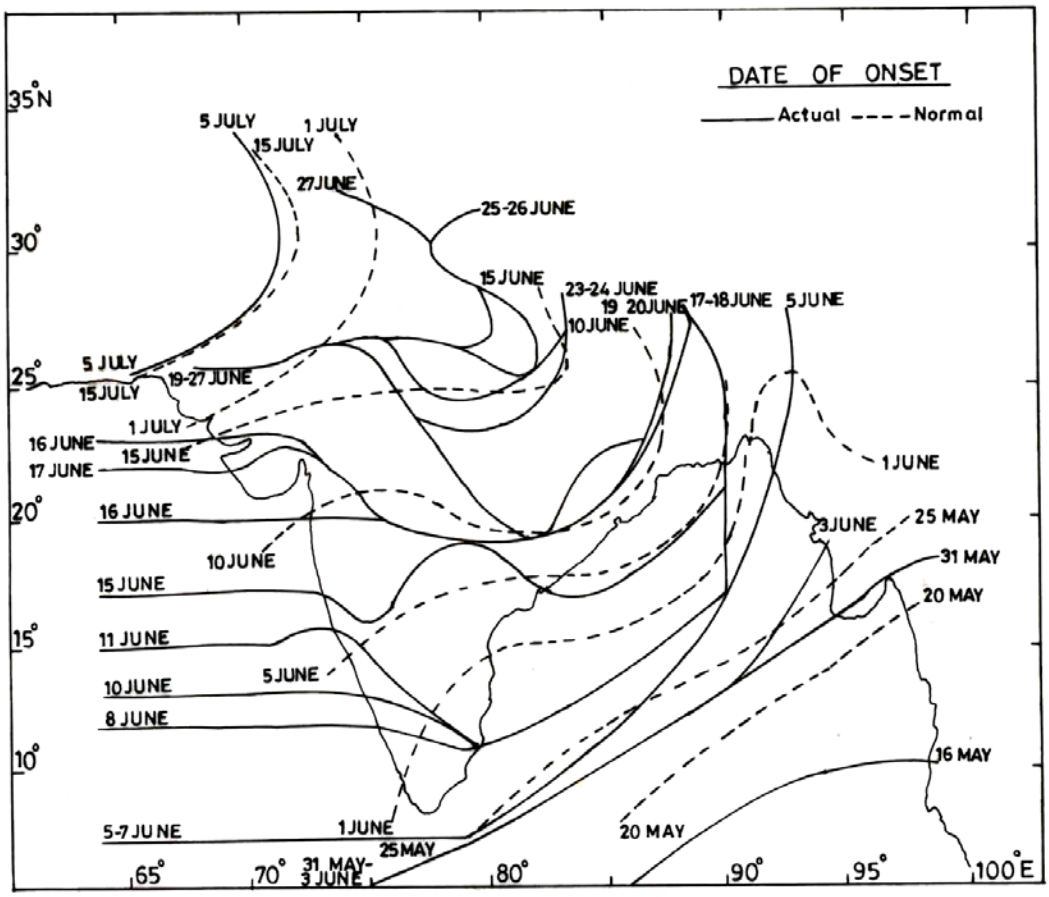



**Fig. 1.** Advance of southwest monsoon 2003

Rainfall activity over peninsular India was quite subdued in the initial fortnight and was rather good in the second one. Thenceforth it remained good except over Karnataka and Kerala until week ending on 20 August. However, first half of August gave good rainfall over these regions. Again it was generally subdued over the peninsula till the end of September. Over the central parts of the country rainfall was quite subdued during the initial two weeks of June, when monsoon was yet to set in. Thereafter, it remained above normal throughout, except over Madhya Maharashtra, Marathwada and Vidarbha. Madhya Maharashtra experienced *deficient* rainfall spells during the later 3 weeks each of July, August and September, whereas in Marathwada and Vidarbha rainfall was quite subdued during the periods 30 July to 20 August and 3 to 24 September. Gujarat state also experienced dry spells of shorter duration towards the later half of the season. Over northwest India, longer dry spells were comparatively less after the advance of monsoon over there, except over east Rajasthan, where rainfall activity was subdued throughout August. Over the northern parts of the country also, it was well distributed in time, except for Bihar experiencing a deficient rainfall spell from 20 August to 17 September and Gangetic West Bengal from 27 August to the end of season. Over northeast India also, it was well distributed in time, with the only prolonged subdued spell being those from 3 September to the end of the season in Arunachal Pradesh, 23 July to 13 August & 3 to 24 September in Assam & Meghalaya and 13 August to 3 September in Nagaland-Manipur-Mizoram-Tripura.

### 3.2.2. *Weekly cumulative rainfall distribution*

Meteorological sub-divisionwise cumulative rainfall departures (percentage departure from normal) during the southwest monsoon season from 1 June to 30 September comprising of 18 weeks are given in Fig. 2(b).

# Progress of the monsoon week by week

**1 June – 30 September 2003**

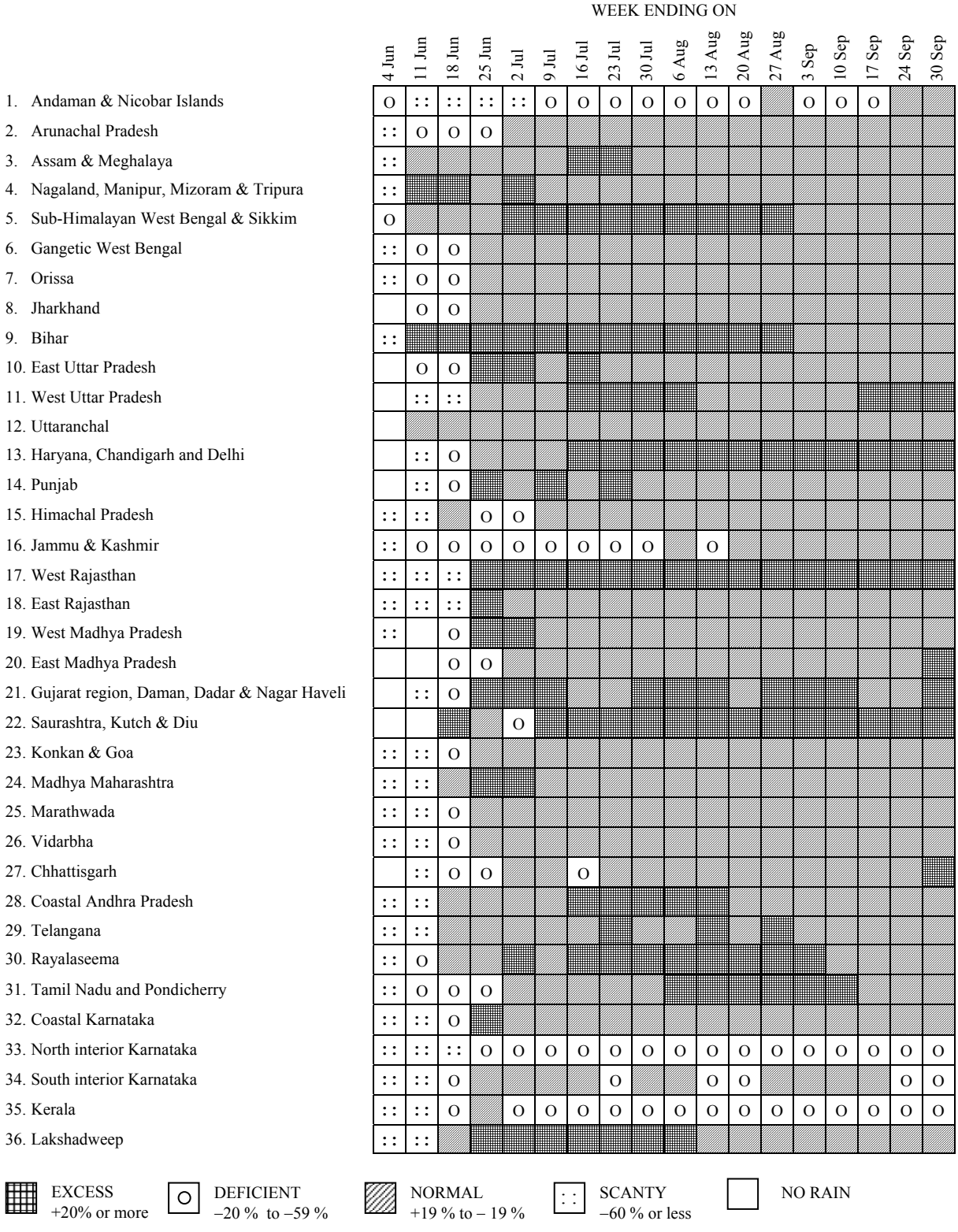



**Fig. 2(a)**

# Progress of the monsoon week by week (cumulative)

**1 June – 30 September 2003**

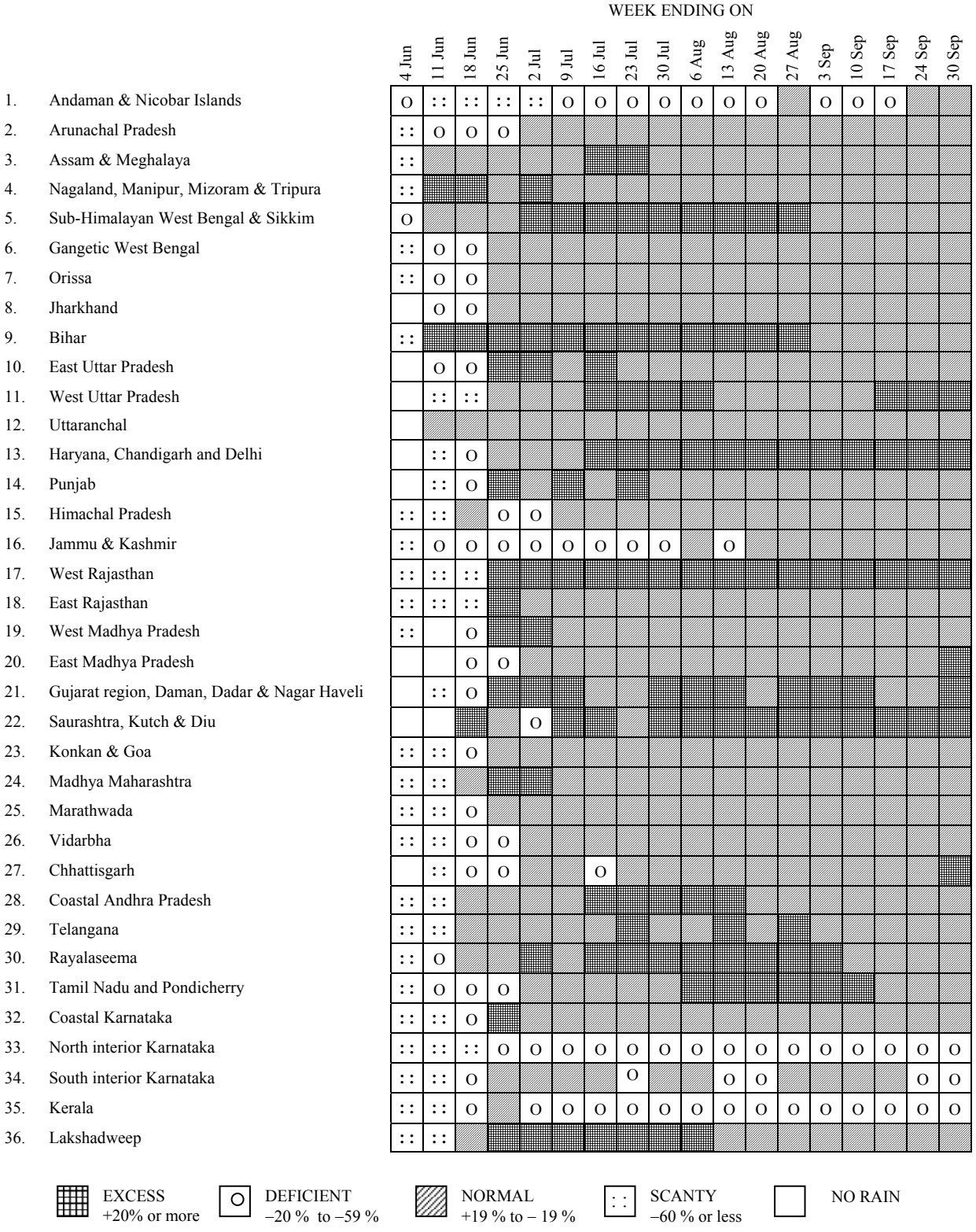



**Fig. 2(b)**

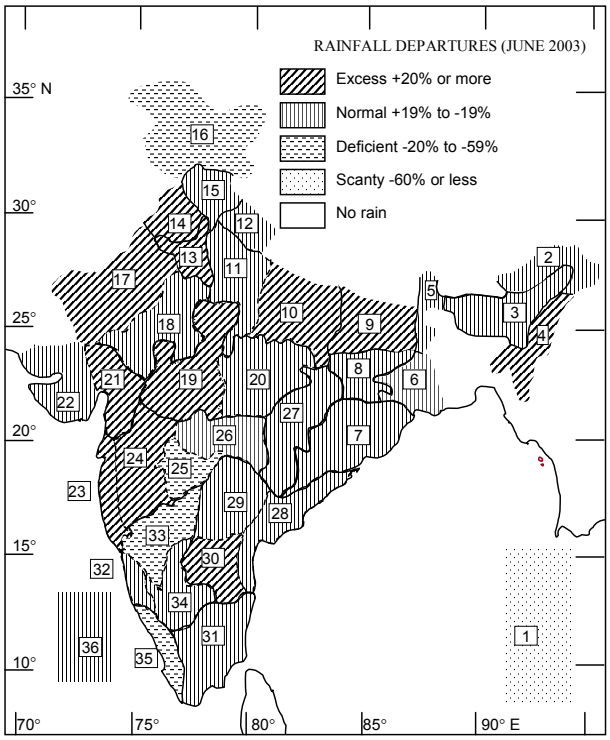



**Fig. 3.** Sub-divisionwise seasonal rainfall departure from normal (%) for the period (Jun - Sep 2003). 36 Sub-divisions are indicated by numbers on the map & bold letters in legend below. The rainfall anomaly values for these sub-divisions are indicated below :

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | –71 | **7** | 3 | **13** | 25 | **19** | 22 | **25** | –23 | **31** | –12 |
| **2** | –4 | **8** | –9 | **14** | 48 | **20** | –8 | **26** | 15 | **32** | 11 |
| **3** | 15 | **9** | 95 | **15** | –12 | **21** | 69 | **27** | –10 | **33** | –34 |
| **4** | 32 | **10** | 27 | **16** | –22 | **22** | 19 | **28** | –5 | **34** | –4 |
| **5** | 16 | **11** | 8 | **17** | 64 | **23** | 21 | **29** | –11 | **35** | –22 |
| **6** | 13 | **12** | –10 | **18** | 13 | **24** | 53 | **30** | 20 | **36** | 12 |

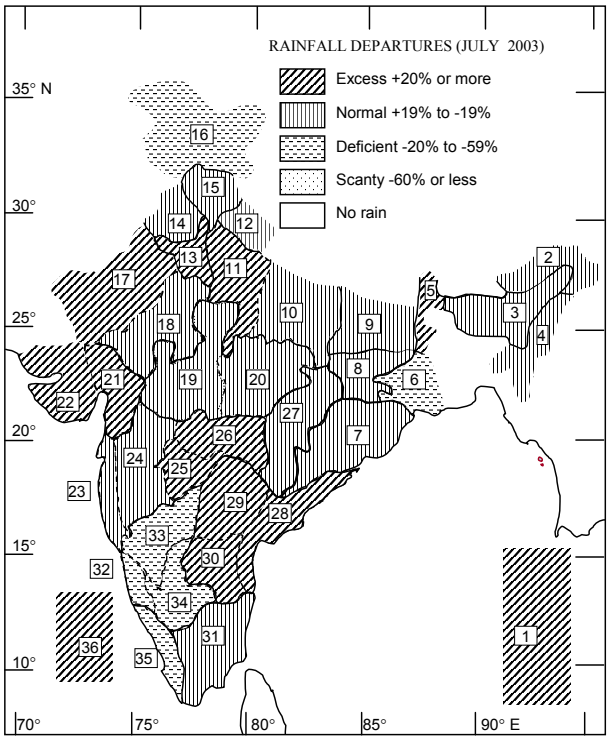



**Fig. 4.** Sub-divisionwise seasonal rainfall departure from normal (%) for the period (Jul 2003). 36 Sub-divisions are indicated by numbers on the map & bold letters in legend below. The rainfall anomaly values for these sub-divisions are indicated below :

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 20 | **7** | 5 | **13** | 67 | **19** | 3 | **25** | 28 | **31** | 10 |
| **2** | 8 | **8** | –17 | **14** | 8 | **20** | 8 | **26** | 23 | **32** | –20 |
| **3** | 4 | **9** | 8 | **15** | 3 | **21** | 32 | **27** | 9 | **33** | –27 |
| **4** | –16 | **10** | –11 | **16** | –23 | **22** | 65 | **28** | 45 | **34** | –26 |
| **5** | 54 | **11** | 35 | **17** | 58 | **23** | –5 | **29** | 33 | **35** | –33 |
| **6** | –23 | **12** | 4 | **18** | 2 | **24** | –18 | **30** | 71 | **36** | 42 |

Until the week ending on 18 June, more than 66% of the sub-divisions remained either *deficient* or *scanty*. Thereafter the cumulative rainfall remained *excess* or *normal* over more than 80% of the sub-divisions until the end of the season.

North interior Karnataka and Kerala were the maximum rainfall *deficient* sub-divisions. They remained *deficient* all through the season, except for Kerala reporting the percentage departure to be normal for the week ending on 25 June. South Interior Karnataka remained *deficient* until the week ending on 18 June, and also for the weeks ending on 23 July, 13 & 20 August and during the later half of September. Rainfall was not so well distributed in Andaman & Nicobar Islands as well, which remained *deficient*/ *scanty* until the week ending on 20 August and again during the period 27 August to 17 September. Over Jammu & Kashmir also, rainfall remained *deficient* until the week ending on 30 July. Other than these, all other sub-divisions were reported to be having either *excess*/*normal* rainfall, with exceptions of one or two weeks of deficient rainfall.

### 3.3. *Monthly rainfall distribution*

Figs. 3-6 show monthwise distribution of monsoon rainfall. Rainfall figures and departures for each month and season as a whole, sub-divisionwise, are given in Table 1.

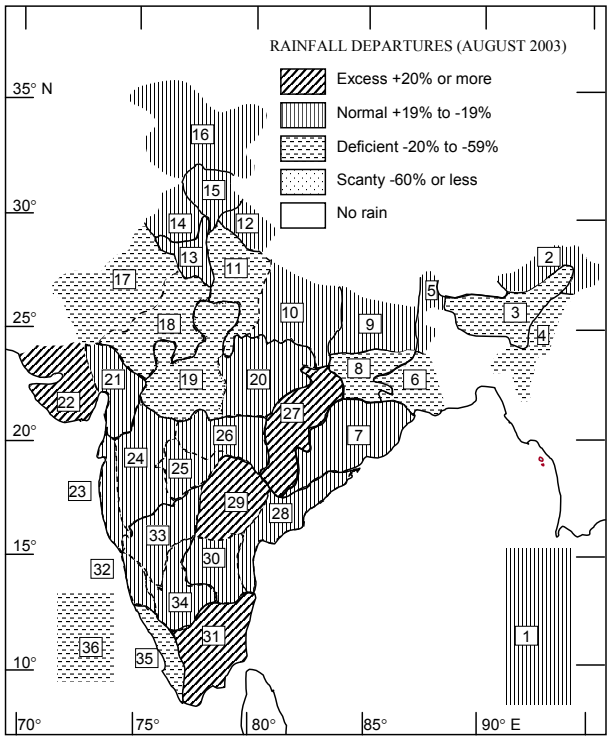



**Fig. 5.** Sub-divisionwise seasonal rainfall departure from normal (%) for the period (Aug 2003). 36 Sub-divisions are indicated by numbers on the map & bold letters in legend below. The rainfall anomaly values for these sub-divisions are indicated below :

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | –10 | **7** | 12 | **13** | 2 | **19** | –32 | **25** | –15 | **31** | 61 |
| **2** | –3 | **8** | –21 | **14** | –10 | **20** | –4 | **26** | –12 | **32** | –19 |
| **3** | –22 | **9** | 2 | **15** | 15 | **21** | 8 | **27** | 27 | **33** | –7 |
| **4** | –31 | **10** | 3 | **16** | –6 | **22** | 60 | **28** | –4 | **34** | –6 |
| **5** | –17 | **11** | –26 | **17** | –21 | **23** | –12 | **29** | 35 | **35** | –27 |
| **6** | –25 | **12** | –1 | **18** | –30 | **24** | –15 | **30** | 16 | **36** | –57 |

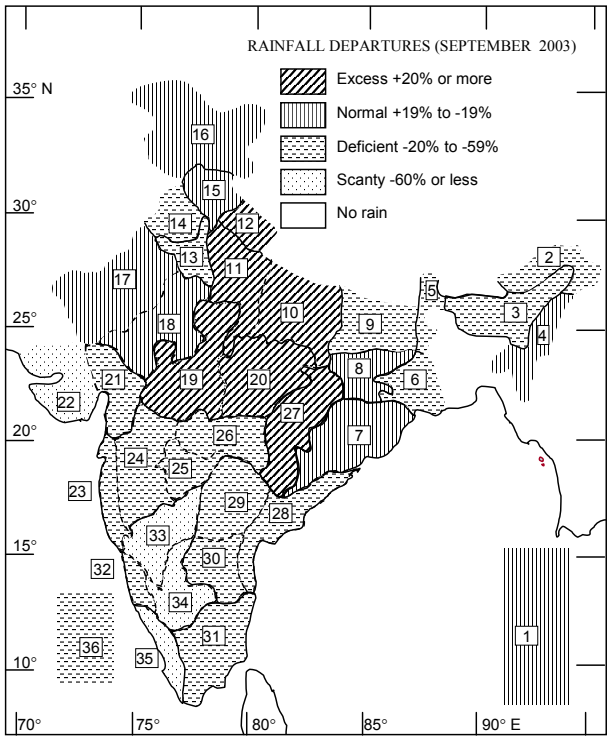



**Fig. 6.** Sub-divisionwise seasonal rainfall departure from normal (%) for the period (Sep 2003). 36 Sub-divisions are indicated by numbers on the map & bold letters in legend below. The rainfall anomaly values for these sub-divisions are indicated below :

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | –8 | **7** | 2 | **13** | –37 | **19** | 45 | **25** | –58 | **31** | –44 |
| **2** | –46 | **8** | –13 | **14** | –37 | **20** | 105 | **26** | –37 | **32** | –44 |
| **3** | –29 | **9** | –28 | **15** | –5 | **21** | –26 | **27** | 48 | **33** | –63 |
| **4** | –3 | **10** | 70 | **16** | 18 | **22** | –71 | **28** | –23 | **34** | –71 |
| **5** | –21 | **11** | 132 | **17** | –1 | **23** | –25 | **29** | –55 | **35** | –61 |
| **6** | –36 | **12** | 48 | **18** | 14 | **24** | –40 | **30** | –36 | **36** | –49 |

### 3.4. *Seasonal rainfall distribution*

Meteorological sub-divisionwise seasonal rainfall distribution in terms of percentage departures from normal is given in Fig. 7 and in Table 1. The seasonal rainfall was *excess* in 7, *normal* in 26 and *deficient* in 3 meteorological Sub-divisions. Seasonal total rainfall for the country as a whole was slightly above normal and country received 102% of its long period average rainfall.

### 3.5. *Districtwise distribution of monsoon rainfall*

Seventy-five percent of the districts received *excess* / *normal* rainfall and the rest 25% received deficient / scanty rainfall during the period 1 June – 30 September 2003.

Table 2 gives a comparison with the past 5 years.

### 3.6. *Withdrawal of southwest monsoon*

Southwest monsoon withdrew from parts of west Rajasthan and Punjab on 17 September with a delay of about 2 weeks. Withdrawal completed from northwest India by 1st Oct, (in the near normal date), from central India by 11 Oct (a few days ahead of the normal date) from entire northeast India and some parts of southern peninsula by 13 Oct (2 days ahead of the normal date). It withdrew from the entire country by 15 Oct which coincided with the normal date of withdrawal of southwest monsoon. (Fig. 8).

**TABLE 1**

**Rainfall figures (mm) for each month and season as a whole (June – September 2003)**

| S. No. | Meteorological sub – divisions | June | | | July | | | August | | | September | | | Season | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Actual (mm) | Normal (mm) | Dep. (%) | Actual (mm) | Normal (mm) | Dep. (%) | Actual (mm) | Normal (mm) | Dep. (%) | Actual (mm) | Normal (mm) | Dep. (%) | Actual (mm) | Normal (mm) | Dep. (%) |
| 1. | A. & N. Islands | 121 | 422 | -71 | 443 | 369 | 20 | 330 | 365 | -10 | 370 | 404 | -8 | 1263 | 1560 | -19 |
| 2. | Arunachal Pradesh | 500 | 518 | -4 | 680 | 630 | 8 | 397 | 407 | -3 | 206 | 380 | -46 | 1776 | 1935 | -8 |
| 3. | Assam & Meghalaya | 631 | 551 | 15 | 559 | 536 | 4 | 321 | 414 | -22 | 228 | 320 | -29 | 1842 | 1821 | 1 |
| 4. | Naga., Mani., Mizo. and Tripura | 521 | 396 | 32 | 311 | 368 | -16 | 225 | 325 | -31 | 232 | 238 | -3 | 1331 | 1327 | 0 |
| 5. | S. H. W. B. & Sikkim | 591 | 511 | 16 | 946 | 613 | 54 | 400 | 479 | -17 | 357 | 450 | -21 | 2291 | 2053 | 12 |
| 6. | Gangetic West Bengal | 270 | 239 | 13 | 241 | 312 | -23 | 226 | 303 | -25 | 166 | 258 | -36 | 900 | 1111 | -19 |
| 7. | Orissa | 210 | 204 | 3 | 365 | 346 | 5 | 406 | 363 | 12 | 251 | 247 | 2 | 1222 | 1159 | 5 |
| 8. | Jharkhand | 172 | 189 | -9 | 277 | 332 | -17 | 250 | 316 | -21 | 209 | 240 | -13 | 926 | 1077 | -14 |
| 9. | Bihar | 320 | 164 | 95 | 361 | 333 | 8 | 294 | 289 | 2 | 159 | 221 | -28 | 1108 | 1007 | 10 |
| 10. | East Uttar Pradesh | 128 | 101 | 27 | 272 | 305 | -11 | 307 | 298 | 3 | 331 | 195 | 70 | 1047 | 899 | 16 |
| 11. | West Uttar Pradesh | 72 | 66 | 8 | 355 | 263 | 35 | 209 | 283 | -26 | 344 | 148 | 132 | 969 | 760 | 28 |
| 12. | Uttaranchal | 151 | 168 | -10 | 471 | 455 | 4 | 442 | 446 | -1 | 317 | 215 | 48 | 1408 | 1284 | 10 |
| 13. | Haryana, Chandigarh & Delhi | 61 | 49 | 25 | 310 | 185 | 67 | 188 | 185 | 2 | 61 | 97 | -37 | 616 | 515 | 20 |
| 14. | Punjab | 62 | 42 | 48 | 206 | 191 | 8 | 154 | 171 | -10 | 65 | 103 | -37 | 480 | 507 | -5 |
| 15. | Himachal Pradesh | 96 | 109 | -12 | 351 | 340 | 3 | 357 | 311 | 15 | 139 | 147 | -5 | 939 | 907 | 3 |
| 16. | Jammu & Kashmir | 39 | 50 | -22 | 130 | 168 | -23 | 151 | 161 | -6 | 96 | 81 | 18 | 415 | 461 | -10 |
| 17. | West Rajasthan | 48 | 29 | 64 | 179 | 113 | 58 | 80 | 101 | -21 | 45 | 45 | -1 | 352 | 289 | 22 |
| 18. | East Rajasthan | 68 | 61 | 13 | 231 | 227 | 2 | 167 | 237 | -30 | 122 | 107 | -14 | 590 | 631 | -6 |
| 19. | West Madhya Pradesh | 129 | 106 | 22 | 315 | 306 | 3 | 216 | 317 | -32 | 259 | 180 | 45 | 934 | 908 | 3 |
| 20. | East Madhya Pradesh | 135 | 146 | -8 | 411 | 382 | 8 | 376 | 391 | -4 | 412 | 201 | 105 | 1343 | 1121 | 20 |
| 21. | Gujarat Region | 238 | 141 | 69 | 532 | 402 | 32 | 345 | 318 | 8 | 131 | 177 | -26 | 1245 | 1037 | 20 |
| 22. | Saurashtra & Kutch | 93 | 105 | -12 | 358 | 217 | 65 | 236 | 148 | 60 | 23 | 81 | -71 | 710 | 550 | 29 |
| 23. | Konkan & Goa | 838 | 691 | 21 | 1010 | 1069 | -5 | 620 | 705 | -12 | 260 | 345 | -25 | 2746 | 2810 | -2 |
| 24. | Madhya Maharashtra | 218 | 143 | 53 | 218 | 264 | -18 | 164 | 192 | -15 | 91 | 151 | -40 | 691 | 751 | -8 |
| 25. | Marathwada | 111 | 144 | -23 | 246 | 193 | 28 | 165 | 195 | -15 | 72 | 172 | -58 | 595 | 703 | -15 |
| 26. | Vidarbha | 190 | 165 | 15 | 400 | 326 | 23 | 263 | 298 | -12 | 114 | 180 | -37 | 923 | 969 | -5 |
| 27. | Chattisgarh | 165 | 183 | -10 | 418 | 383 | 9 | 480 | 379 | 27 | 337 | 228 | 48 | 1403 | 1173 | 20 |
| 28. | Coastal Andhra Pradesh | 102 | 107 | -5 | 247 | 170 | 45 | 158 | 164 | -4 | 129 | 168 | -23 | 635 | 608 | 4 |
| 29. | Telangana | 121 | 136 | -11 | 324 | 244 | 33 | 299 | 222 | 35 | 78 | 173 | -55 | 818 | 775 | 6 |
| 30. | Rayalaseema | 71 | 60 | 20 | 156 | 91 | 71 | 113 | 97 | 16 | 85 | 132 | -36 | 415 | 381 | 9 |
| 31. | Tamil Nadu | 39 | 45 | -12 | 82 | 75 | 10 | 149 | 93 | 61 | 62 | 111 | -44 | 342 | 323 | 6 |
| 32. | Coastal Karnataka | 1010 | 909 | 11 | 954 | 1186 | -20 | 624 | 775 | -19 | 179 | 318 | -44 | 2771 | 3188 | -13 |
| 33. | North Interior Karnataka | 64 | 97 | -34 | 92 | 126 | -27 | 101 | 109 | -7 | 55 | 147 | -63 | 310 | 478 | -35 |
| 34. | South Interior Karnataka | 137 | 142 | -4 | 179 | 243 | -26 | 163 | 174 | -6 | 40 | 139 | -71 | 519 | 698 | -26 |
| 35. | Kerala | 532 | 684 | -22 | 501 | 748 | -33 | 325 | 443 | -27 | 102 | 262 | -61 | 1461 | 2136 | -32 |
| 36. | Lakshadweep | 365 | 326 | 12 | 401 | 282 | 42 | 92 | 213 | -57 | 84 | 164 | -49 | 942 | 985 | -4 |

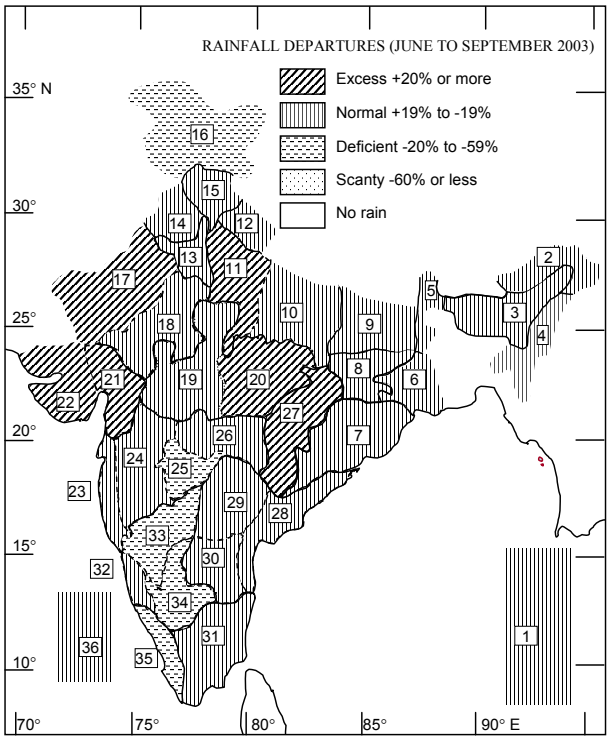



**Fig. 7.** Sub-divisionwise seasonal rainfall departure from normal (%) for the period (Jun - Sep 2003). 36 Sub-divisions are indicated by numbers on the map & bold letters in legend below. The rainfall anomaly values for these sub-divisions are indicated below :

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | –19 | **7** | 5 | **13** | 20 | **19** | 3 | **25** | –15 | **31** | 6 |
| **2** | –8 | **8** | –14 | **14** | –5 | **20** | 20 | **26** | –5 | **32** | –13 |
| **3** | 1 | **9** | 10 | **15** | 3 | **21** | 20 | **27** | 20 | **33** | –35 |
| **4** | 0 | **10** | 16 | **16** | –10 | **22** | 29 | **28** | 4 | **34** | –26 |
| **5** | 12 | **11** | 28 | **17** | 22 | **23** | –2 | **29** | 6 | **35** | –32 |
| **6** | –19 | **12** | 10 | **18** | –6 | **24** | –8 | **30** | 9 | **36** | –4 |

**TABLE 2**

**Districtwise distribution of monsoon rainfall for the years 1998 – 2003**

| Years | Excess/Normal | Deficient/Scanty |
|---|---|---|
| 1998 | 83 | 17 |
| 1999 | 67 | 33 |
| 2000 | 65 | 35 |
| 2001 | 68 | 32 |
| 2002 | 39 | 61 |
| 2003 | 75 | 25 |

**TABLE 3**

**SST Anomaly Indices (ENSO)**

| Month | Pacific SSTA (° C) | | | SOI |
|---|---|---|---|---|
| | Nino 1+2 0° - 10° S 90° - 80° W | Nino 3 5° N - 5° S 150° - 90° W | Nino 4 5° N - 5° S 60° E - 150° W | |
| Oct 2002 | 0.3 | 1.0 | 0.5 | -0.7 |
| Nov 2002 | 0.6 | 1.4 | 0.6 | -0.6 |
| Dec 2002 | 0.6 | 1.4 | 0.5 | -1.4 |
| Jan 2003 | -0.1 | 0.8 | 0.5 | -0.4 |
| Feb 2003 | -0.2 | 0.3 | 0.3 | -1.2 |
| Mar 2003 | -0.5 | 0.2 | 0.6 | -1.0 |
| Apr 2003 | -1.0 | -0.3 | 0.9 | -0.4 |
| May 2003 | -1.8 | -0.9 | 1.0 | -0.6 |
| Jun 2003 | -1.5 | -0.5 | 1.1 | -1.1 |
| Jul 2003 | -1.1 | 0.2 | 1.2 | 0.2 |
| Aug 2003 | -0.7 | 0.1 | 1.5 | -0.3 |
| Sep 2003 | -0.5 | 0.1 | 1.1 | -0.1 |

Datewise withdrawal of southwest monsoon over different regions until 30 September is given below :

| *Date* | *Regions from which withdrawal took place* | *Remarks* |
|---|---|---|
| 17 Sep | Parts of Rajasthan and Punjab | About 2 weeks delay |
| 19 Sep | Parts of Jammu & Kashmir, some more parts of Punjab, parts of Haryana and most parts of west Rajasthan | 4 to 5 days delay in most of the regions |
| 27 Sep | Entire Jammu & Kashmir, most parts of Himachal Pradesh, Punjab, some parts of Uttaranchal and of west Uttar Pradesh, most parts of Haryana, parts of east Rajasthan, northern parts of Gujarat State and of north Arabian Sea. | With a delay of about a week |
| 29 Sep | Most parts of Uttaranchal, rest Himachal Pradesh, some more parts of west Uttar Pradesh, rest Haryana, most parts of east Rajasthan, some more parts of Gujarat State and of north Arabian Sea | In near normal time in many regions |

### 3.7. *El-Nino phenomenon*

The planetary scale tropical SLP anomalies associated with the Southern Oscillation generally occurred in conjunction with episodes of El-Nino/ La Nina in the tropical Pacific, indicating El-Nino- Southern Oscillation phenomena. The phase and magnitude of the ENSO can be indicated either by the sea surface temperature (SST) anomalies over the Pacific or by Southern Oscillation Index (SOI) expressed as the difference in atmospheric surface pressure between Tahiti, an island station in the southeast Pacific Ocean and Darwin, Australia. In general, during some years an inverse relationship between ENSO and Indian summer monsoon rainfall has been observed.

**TABLE 4**

**Details of the weather systems during June 2003**

| S. No. (1) | System (2) | Period (3) | Place of first location (4) | Direction of movement (5) | Place of dissipation (6) | Remarks (7) |
|---|---|---|---|---|---|---|
| (**A**) | *Low pressure areas* | | | | | |
| 1. | Low pressure area | 19-23 | Gangetic West Bengal and neighbourhood | Northerly | Sub-Himalayan West Bengal & Sikkim and neighbourhood | Was seen as a cyclonic circulation upto mid tropospheric levels over north Bay, tilting southwestwards with height on 15 and over north Bay and adjoining Bangladesh during 16 to 18 |
| (**B**) | *Upper air cyclonic circulations* | | | | | |
| 1. | Between 1.5 & 5.8 kms a.s.l. | 3-5 | Northeast and adjoining east-central Bay off Arakan coast | Quasi-stationary | *In situ* | Became less marked on 6 |
| 2. | Between 3.1 & 4.5 kms a.s.l. | 6-12 | Lakshadweep area and neighbourhood | Northerly | Off Maharashtra - Gujarat coasts | Moved northwards along and off the west coast |
| 3. | Between 2.1 & 5.8 kms a.s.l. | 14-27 | Off south Maharashtra-Goa coasts | Northerly and then northeasterly | Central parts of Uttar Pradesh | Sustained for a long time |
| 4. | Between 0.9 & 5.8 kms a.s.l. | 21-25 | Gujarat Region and neighbourhood | Northerly | Central Pakistan and neighbourhood | Became less marked on 26 |
| 5. | Between 3.1 & 5.8 kms a.s.l. | 28-29 | Saurashtra & Kutch and neighbourhood | Quasi-stationary | *In situ* | Became less marked on 30 |
| (**C**) | *Embedded cyclonic circulation* | | | | | |
| 1. | Lower levels | 14 | Off Goa-Karnataka coasts | Stationary | *In situ* | Lay embedded on the off-shore trough |
| (**D**) | *Eastward moving systems* | | | | | |
| 1. | Upper air cyclonic circulation upto mid tropospheric level | 2-6 | North Pakistan and adjoining Jammu & Kashmir | Eastnortheasterly | Uttaranchal and neighbourhood | Moved away on 7 |
| 2. | Do | 9-11 | Do | Northeasterly | Jammu & Kashmir and neighbourhood | Moved away on 12 |
| 3. | Do | 12-16 | Do | Do | Do | Moved away on 17 |
| 4. | Do | 17-22 | Do | Eastnortheasterly | Eastern parts of Jammu & Kashmir and neighbourhood | Moved away on 23 |
| 5. | Upper air cyclonic circulation upto mid tropospheric level | 23-28 | North Pakistan and adjoining Jammu & Kashmir | Eastnortheasterly | Eastern parts of Jammu & Kashmir and neighbourhood | Moved away on 29 |
| 6. | Do | 28-30 | North Pakistan and neighbourhood | Northeasterly | Jammu & Kashmir and neighbourhood | Moved away on 30 evening |
| 7. | Do | 29 Jun - 2 Jul | Central Pakistan and adjoining west Rajasthan | Do | Northwest Rajasthan and neighbourhood | Became less marked on 3 July |
| (**E**) | *North-South troughs* | | | | | |
| 1. | Between 3.1 & 4.5 kms a.s.l. | 1-2 | East Rajasthan to south Maharashtra-Goa coasts | Quasi-stationary | Gujarat Region to Konkan & Goa | Became less marked on 3 |
| (**F**) | *East-West troughs* | | | | | |
| 1. | At 0.9 km a.s.l. | 4-8 | Punjab to north Bay | Quasi-Stationary | Punjab to Tripura | Manifested as the heat trough at sea level thereafter |

**TABLE 5**

**Details of the weather systems during July 2003**

| S. No. | System | Period | Place of first location | Direction of movement | Place of dissipation | Remarks |
|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| (**A**) | *Depressions* | | | | | |
| 1. | Deep Depression | 25-28 | Gangetic West Bengal and adjoining areas of northwest Bay, Orissa, and Jharkhand | Westnorthwesterly | Northwest Madhya Pradesh and neighbourhood | Formed as a low pressure area over Gangetic West Bengal and neighbouring areas on 22. It drifted over to northwest Bay and neighbourhood on 23 and concentrated into a depression on 25 morning. It intensified into a deep depression in the same day evening. Following a northwesterly track, it weakened into a depression on 27 morning and subsequently into a low pressure area over south Rajasthan and neighbourhood in the evening of 28, which merged with the heat low on 30 |
| (**B**) | *Low pressure areas* | | | | | |
| 1. | Low pressure area | 5 | West-central and adjoining northwest Bay off north Andhra –south Orissa coasts | Stationary | *In situ* | Associated cyclonic circulation extending upto mid tropospheric levels traversed upto southeast Madhya Pradesh and became less marked on 8 |
| 2. | Do | 17-18 | West-central Bay off north Andhra-south Orissa coasts | Northwesterly | Southern parts of Orissa and neighbourhood | First seen as a cyclonic circulation between 1.5 & 5.8 kms a.s.l., tilting southwestwards with height over northwest Bay and neighbourhood on 14. Though the low pressure area became less marked on 19, the associated cyclonic circulation remained over the region and caused the formation of the first depression of the season |
| 3. | Well marked low pressure area | 26-29 | Northeast and adjoining northwest Arabian Sea | Quasi-stationary | *In situ* | Under the influence of an upper air cyclonic circulation a low pressure area formed over south Pakistan and adjoining areas of Saurashtra & Kutch and southwest Rajasthan on 26 morning. It became well-marked in the same evening, moved over to northern parts of Arabian sea during 27 to 29 and became less marked on 30 |
| 4. | Do | 31 Jul (eve) – 2 Aug | Bangladesh and adjoining north Bay | Westerly | Chattisgarh and adjoining Jharkhand | Formed under the influence of a cyclonic circulation over Bangladesh and neighbourhood extending upto mid tropospheric levels, tilting southwestwards with height on 30 and 31 July. After the low pressure area became less marked, the associated cyclonic circulation in the lower levels moved over to east Madhya Pradesh and adjoining Chattisgarh on 5 and became less marked on 6 |
| (**C**) | *Upper air cyclonic circulations* | | | | | |
| 1. | Between 2.1 & 5.8 kms a.s.l. | 1-8 | Gujarat Region and adjoining west Rajasthan | Quasi-stationary | Saurashtra & Kutch and neighbourhood | Tilted southwestwards with height on most of the days |
| 2. | Between 3.1 & 5.8 kms a.s.l. | 8-11 | Andaman Sea | Northwesterly | Chattisgarh and neighbourhood | It extended upto mid tropospheric levels, tilting southwestwards with height on 10 |
| 3. | Mid tropospheric levels | 4-7 | Northwest Rajasthan and neighbourhood | Do | Central Pakistan and adjoining west Rajasthan | Became less marked on 8 |

**TABLE 5 (*Contd.*)**

| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|
| 4. | Between 3.6 & 5.8 kms a.s.l. | 12-19 | Gujarat Region and neighbourhood | Quasi-stationary | *In situ* | Tilted southwestwards with height |
| 5. | Between 0.9 & 3.1 kms a.s.l. | 9 | Jharkhand and neighbourhood | Quasi-stationary | *In situ* | Was seen as a trough in westerlies from Sub-Himalayan West Bengal & Sikkim to north Orissa on 8 |
| 6. | Between 1.5 & 3.6 kms a.s.l. | 15 | Uttaranchal and neighbourhood | Do | Do | Became less marked on 16 |
| 7. | Lower tropospheric levels | 21-24 | West Uttar Pradesh and neighbourhood | Easterly | Central parts of Uttar Pradesh | Became less marked on 25 |
| (**D**) | *Eastward moving systems* | | | | | |
| 1. | Upper air cyclonic circulation upto mid tropospheric levels | 6-8 | North Pakistan and adjoining Jammu & Kashmir | Eastnortheasterly | Eastern parts of Jammu & Kashmir | Moved away on 9 |
| 2. | Do | 9-12 | Do | Do | Do | Moved away on 13 |
| 3. | Low pressure area | 11-13 | Haryana and adjoining areas of east Rajasthan and west Uttar Pradesh | Easterly | West Uttar Pradesh and neighbourhood | Formed under the influence of a cyclonic circulation over central parts of Rajasthan and adjoining areas on 10. Though the low pressure area became less marked on 14, the associated cyclonic circulation extending upto mid tropospheric levels drifted gradually over to Vidarbha and neighbourhood and became less marked on 19 |
| 4. | Upper air cyclonic circulation upto mid tropospheric levels | 13-19 | North Pakistan and adjoining Jammu & Kashmir | Eastnorth-easterly | Eastern parts of Jammu & Kashmir and neighbourhood | Moved away on 20 |
| 5. | Do | 20-24 | Do | Do | Jammu & Kashmir and neighbourhood | Moved away on 25 |
| 6. | Do | 25-27 | Do | Do | Do | Moved away on 28 |
| 7. | Do | 28-31 | Do | Do | Do | Moved away on 1 August |

Table 3 depicts the monthly values of SST anomaly indices at various geographical regions of Tropical Pacific and SOI for the period October 2002 to September 2003. The monthly SST conditions continued to reflect neutral conditions across the Tropical Pacific. The Nino 1+2 index showed slight cooling from the beginning of the year until the end of the monsoon season. On the other hand, the Nino 4 index showed persistent warming from October 2002 to September 2003. The Nino 3 index after reaching the lowest positive value of 0.2 in March 2003 became negative till June 2003 and again increased to slight positive value (up to 0.2) during July to September 2003.

## 4. Chief synoptic features of southwest monsoon

The synoptic disturbances which affected the Indian monsoon region in June, July, August and September are given in Tables, 4, 5, 6 and 7 respectively.

### 4.1. Cyclonic storms/depressions

No cyclonic storm formed during the season. However, two depressions formed during the season, both over the Bay of Bengal. The first one, a deep depression (25 – 28 July) which subsequently moved inland and caused rainfall over the central parts of the country and

**TABLE 6**

**Details of the weather systems during August 2003**

| S. No. | System | Period | Place of first location | Direction of movement | Place of dissipation | Remarks |
|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| (**A**) | *Depressions* | | | | | |
| 1. | Depression | 27 eve-28 eve | Northwest Bay | Westnorthwesterly | Orissa and neighbourhood | Formed as a low pressure area on 25, which became well marked on 27 morning. It intensified into 1 depression on 27 evening. The depression rapidly weakened into a low pressure area on 29, and traveled northwestwards upto southeast Uttar Pradesh. It became less marked on 31 August. Associated upper air cyclonic circulation became less marked on 2 September |
| (**B**) | *Low pressure areas* | | | | | |
| 1. | Low pressure area | 3-7 | Northwest Bay and adjoining areas of Gangetic West Bengal and north Orissa | Oscillatory | West-central and adjoining northwest Bay off north Andhra–south Orissa coasts | Became less marked on 8. However, the associated upper air cyclonic circulation extending upto 7.6 kms a.s.l. tilting southwestwards with height traversed upto central parts of Uttar Pradesh and adjoining Madhya Pradesh on 14, which caused the formation of the subsequent low pressure area |
| 2. | Low pressure area | 15-17 | Central Uttar Pradesh and adjoining east Madhya Pradesh | Northwesterly | Northwest Uttar Pradesh and adjoining Uttaranchal | Became less marked on 18 |
| 3. | Well marked low pressure area | 21-26 | West-central and adjoining northwest Bay & coastal areas of Orissa-north Andhra Pradesh | Westnorthwesterly | West Rajasthan | Became well marked on 22. Associated upper air cyclonic circulation extended upto 7.6 kms a.s.l. tilting southwestwards with height. Rapidly moved across the country. The remnant upper air cyclonic circulation merged with the heat low on 29 |
| (**C**) | *Upper air cyclonic circulations* | | | | | |
| 1. | Mid tropospheric levels | 1-13 | Central Pakistan and adjoining west Rajasthan | Oscillatory | Saurashtra & Kutch and neighbourhood | Lay as a MTC over Saurashtra & Kutch for many days |
| 2. | Between 3.1 & 7.6 kms a.s.l. | 13-22 | Bangladesh and neighbourhood | Westnorthwesterly | West Uttar Pradesh and neighbourhood | Tilted southwestwards with height |
| 3. | Between 1.5 & 3.6 kms a.s.l. | 21-22 | South Pakistan and adjoining Saurashtra & Kutch | Quasi-stationary | Saurashtra & Kutch and neighbourhood | Became less marked on 23 |
| (**D**) | *Eastward moving systems* | | | | | |
| 1. | Upper air cyclonic circulation upto mid tropospheric levels | 1-3 | North Pakistan and adjoining Jammu & Kashmir | Eastnortheasterly | Jammu & Kashmir and neighbourhood | Moved away on 4 |
| 2. | Do | 4-7 | Do | Easterly | Eastern parts of Jammu & Kashmir and neighbourhood | Moved away on 8 |
| 3. | Do | 8-10 | Do | Eastnortheasterly | Jammu & Kashmir and neighbourhood | Moved away on 11 |
| 4. | Do | 11-14 | Do | Do | Do | Moved away on 14 evening |
| 5. | Do | 14 eve-17 | Do | Do | Do | Moved away on 18 |

**TABLE 6 (*Contd.*)**

| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|
| 6. | Upper air cyclonic circulation upto mid tropospheric levels | 18-20 | North Pakistan and adjoining Jammu & Kashmir | Eastnortheasterly | Jammu & Kashmir and neighbourhood | Moved away on 21 |
| 7. | Do | 19 eve-23 | Northwest Rajasthan and adjoining central Pakistan | Northeasterly | Haryana and neighbourhood | Became less marked on 24 |
| 8. | Do | 23-25 | North Pakistan and adjoining Jammu & Kashmir | Eastnortheasterly | Jammu & Kashmir and adjoining Punjab | Moved away on 26 |
| 9. | Do | 26-29 | North Pakistan | Northeasterly | Jammu & Kashmir and neighbourhood | Moved away on 30 |
| 10. | Do | 30 Aug – 2 Sep | North Pakistan and adjoining Punjab and Jammu & Kashmir | Northeasterly | Do | Moved away on 3 September |

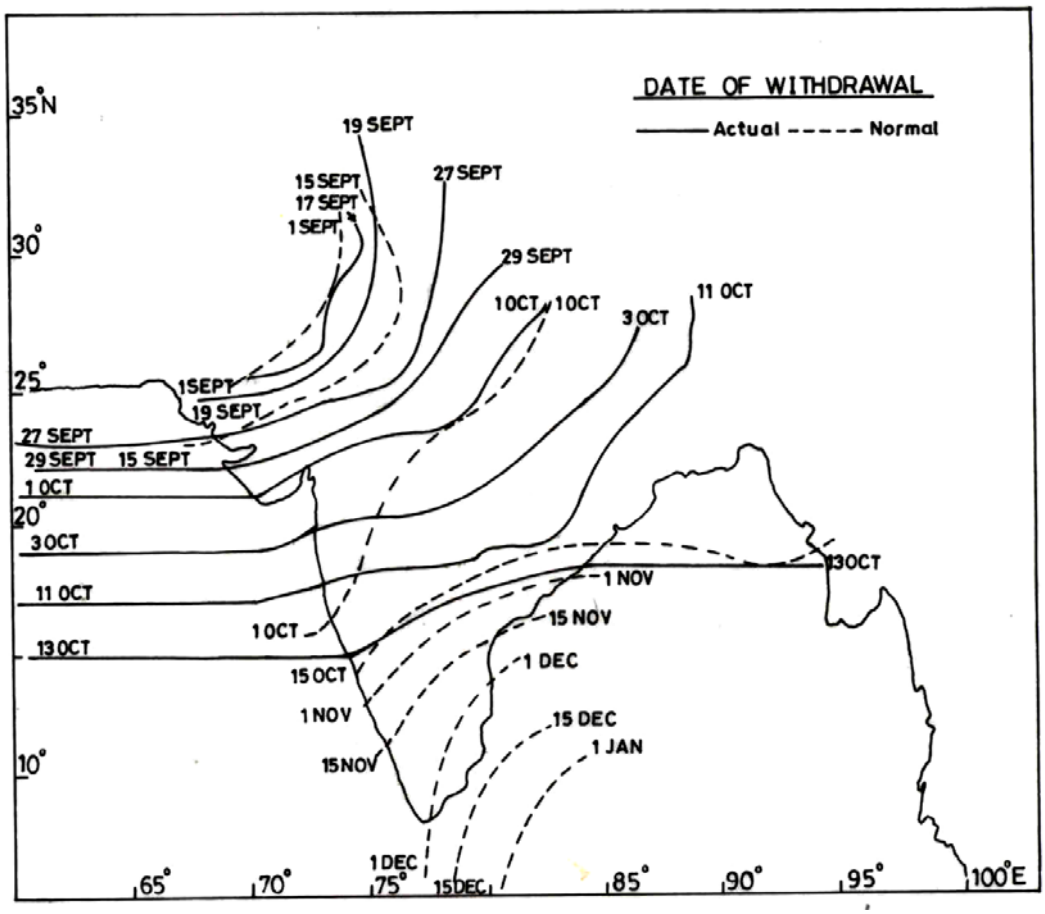



**Fig. 8.** Withdrawal of southwest monsoon 2003

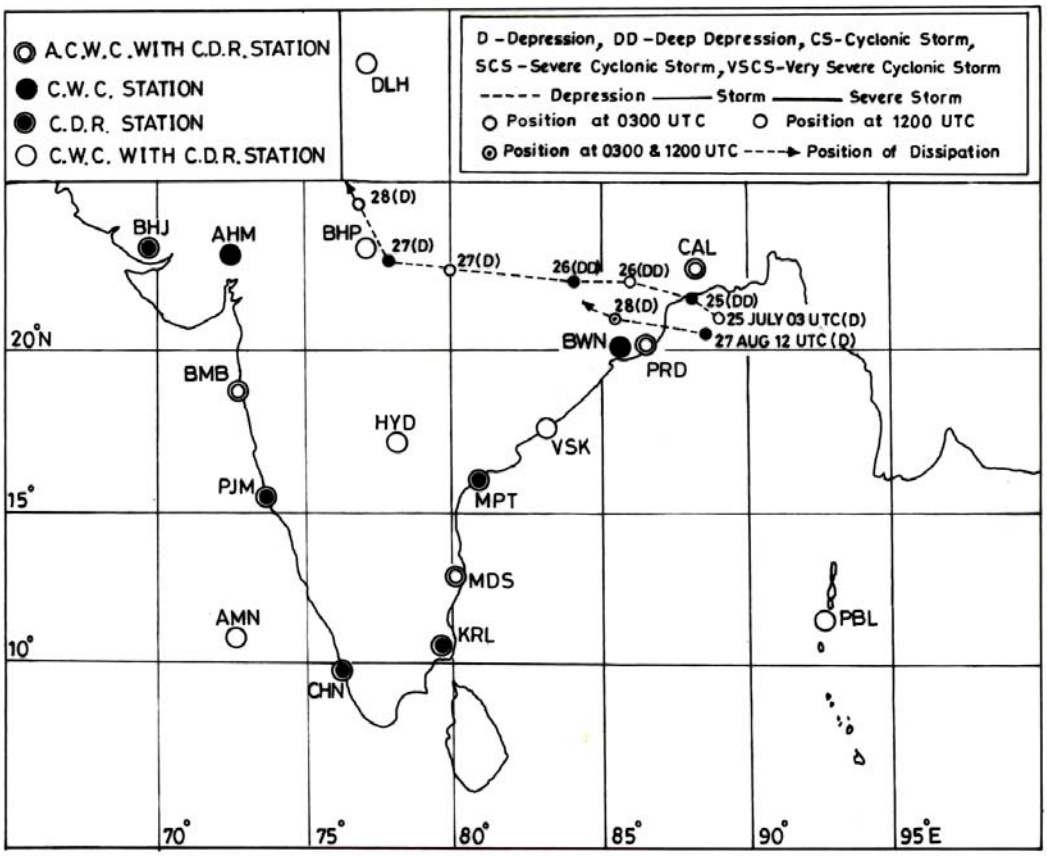



**Fig. 9.** Track of depression during monsoon season 2003

the second, a depression (27 – 28 August) which also moved inland but rapidly weakened into a low pressure area over Chattisgarh and adjoining Orissa. The tracks of the systems are given in Fig. 9. The remaining two months, June and September, were devoid of depressions. Details are given below :

4.1.1. *Deep depression over the Bay of Bengal (25 – 28 July)*

A low pressure area which had been persisting over northern parts of Bay and adjoining land areas since 22, concentrated into a depression over northwest Bay on 25 morning. It lay centred at 0300 UTC of 25, near Lat. 21.0° N/ Long. 89.0° E. Moving northwestwards, it intensified into a deep depression and lay centred near Lat. 21.5° N/ Long. 88.0° E, at 1200 UTC on 25. It rapidly moved inland and lay close to Keonjhargarh at 0300 UTC of 26. Further moving westwards, it lay near Jharsuguda at 1200 UTC of 26. Thereafter, it weakened into a depression and lay centred over east Madhya Pradesh, near Jabalpur at 0300 UTC of 27 and over west Madhya Pradesh, near Bhopal at 1200 UTC of 27. Moving in a northwesterly direction, it lay over northwest Madhya Pradesh, close to Rajgarh at 0300 UTC of 28 and thereafter weakened into a low pressure area over south Rajasthan and neighbourhood in the evening of 28.

Being a monsoon system it followed the expected westnorthwesterly course after crossing coast. The rainfall also had been concentrated in the southwest sector. It moved along the monsoon trough and merged with the heat low after weakening into a low pressure area.

The system did not cause damage to the Orissa – West Bengal coast. However widespread rainfall activity with very heavy rainfall was observed in Orissa on 25. Widespread rainfall activity was also observed in Gangetic West Bengal on the same day.

**TABLE 7**

**Details of the weather systems during September 2003**

| S. No. (1) | System (2) | Period (3) | Place of first location (4) | Direction of movement (5) | Place of dissipation (6) | Remarks (7) |
|---|---|---|---|---|---|---|
| (**A**) | *Low pressure areas* | | | | | |
| 1. | Low pressure area | 1-4 | Gangetic West Bengal and adjoining Jharkhand | Westnorthwesterly | Northeast Madhya Pradesh and neighbourhood | Formed under the influence of an upper air cyclonic circulation over Gangetic West Bengal and adjoining Bangladesh. Became less marked on 5, but the associated upper air cyclonic circulation lay over central parts of Uttar Pradesh on 5 which became less marked on 6 |
| 2. | Well marked low pressure area | 5-11 | Northwest Bay and adjoining west-central Bay off south Orissa-north Andhra coasts. | Northwesterly | Central parts of Uttar Pradesh | Formed under the influence of an upper air cyclonic circulation over northwest Bay off Gangetic West Bengal-Orissa coasts. Became well marked on 6 evening. Though became less marked on 12, associated upper air cyclonic circulation persisted there till 14 |
| 3. | Low pressure area | 11-17 | Northwest Bay off coastal areas of Orissa and Gangetic West Bengal | Westnorthwesterly | Central parts of Uttar Pradesh | Associated upper air cyclonic circulation persisted there on 18, lay over northwest Madhya Pradesh and neighbourhood on 19 and became less marked on 20 |
| 4. | Low pressure area | 23-26 | West-central Bay off North Andhra-south Orissa coasts | Stationary | *In situ* | It formed under the influence of an upper air cyclonic circulation over west-central Bay off the coast during 20 to 22. It became less marked on 27 |
| (**B**) | *Upper air cyclonic circulations* | | | | | |
| 1. | Between 1.5 & 5.8 kms a.s.l. | 4-6 | Central Pakistan and adjoining west Rajasthan | Stationary | *In situ* | Became less marked on 7 |
| 2. | Upto 3.1 kms a.s.l. | 6-7 | West Uttar Pradesh and adjoining northwest Madhya Pradesh | Westerly | Haryana and neighbourhood | Became less marked on 8 |
| 3. | Mid tropospheric levels | 16 Sep – 3 Oct | Northwest Bay off Orissa-West Bengal coasts | Westerly | - | Moved westwards and caused the formation of a well-marked low pressure area over Arabian sea on 4 October |
| 4. | Between 1.5 & 5.8 kms a.s.l. | 13-26 | Gujarat Region and neighbourhood | Quasi-stationary | South Pakistan and adjoining Saurashtra & Kutch and southwest Rajasthan | Became less marked on 27 |
| 5. | Mid tropospheric levels | 23-26 | Central parts of Uttar Pradesh | Stationary | *In situ* | Became less marked on 27 |
| 6. | Between 3.6 & 5.8 kms a.s.l. | 27 Sep - 1 Oct | Chattisgarh and neighbourhood | Westerly | Vidarbha and neighbourhood | Became less marked on 2 October |
| 7. | Upto 3.6 kms a.s.l. | 27 Sep - 1 Oct | Central parts of Uttar Pradesh | Easterly | Bihar and neighbourhood | Became less marked on 1 October |
| 8. | 1.5 & 4.5 kms a.s.l. | 28 | Saurashtra & Kutch and neighbourhood | Stationary | *In situ* | Became less marked on 29 |

**TABLE 7 (*Contd.*)**

| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|
| (**C**) | *Eastward moving systems* | | | | | |
| 1. | Upper air cyclonic circulation upto mid tropospheric levels | 3-4 | North Pakistan and adjoining Jammu & Kashmir | Northeasterly | Jammu & Kashmir and neighbourhood | Moved away on 5 |
| 2. | Do | 5-6 | Do | Do | Do | Moved away on 7 |
| 3. | Do | 6-12 | Do | Do | Do | Moved away on 13 |
| 4. | Do | 13-20 (mor.) | Do | Do | Do | Moved away on 20 evening |
| 5. | Mid tropospheric levels | 20 – 28 | Do | Eastnortheasterly | Uttaranchal and neighbourhood | Moved away on 29 |
| 6. | Do | 26 Sep - 5 Oct | Do | Do | Northern parts of Jammu & Kashmir | Moved away on 6 October |

4.1.2. *Depression over Bay of Bengal (27-28 Aug)*

A well marked low pressure area over northwest Bay, concentrated into a depression, which lay centred at 1200 UTC of 27 near Lat. 20.5° N/Long. 88.5° E. It moved in a westnorthwesterly direction and crossed Orissa coast near Chandbali in the early morning of 28. It lay centred at 0300 UTC of 28, near Lat. 21.0° N/Long. 85.5° E, close to Angul and remained practically stationary over there till the evening. Subsequently moving westwards, it weakened into a low pressure area over Chattisgarh and adjoining Orissa on 29.

However, widespread rainfall activity with *heavy* to *very heavy* rain at a few places in Orissa and fairly widespread rain in West Bengal was reported on 27 August.

4.2. *Low pressure areas/well-marked low pressure areas (LPA/WMLPA)*

During the season, altogether 12 low pressure areas / well marked low pressure areas formed during the season. Most of them originated as upper air cyclonic circulations. Except 4, all of them formed over the oceanic area and subsequently moved over to land. Monthwise breakup of the systems is 1 in June, 4 in July, 3 in August and 4 in September. The total number of low pressure areas during the past 5 years *viz*., 1998 to 2003 are 9, 11, 13, 10, 10 & 12 respectively.

4.3. *Upper Air Cyclonic Circulations (CYCIR)*

There were 24 upper air cyclonic circulations (in lower and upper tropospheric levels) formed during the season.

The month wise break up of these are 6 in June, 7 in July, 3 in August and 8 in September.

4.4. *Off-shore Trough*

Off-shore trough along different parts of the west coast (surface and lower levels) persisted on most of the days from 6 June to 17 September except during 18 – 21 August, 24 – 26 August, 4 September, 9 – 10 September and 12 – 15 September.

The details of the position of the Off-shore trough for 2003 are given in Table 8(a) and that for 1998-2002 are given in Table 8 (b).

4.5. *Eastward moving cyclonic circulations/western disturbances*

There were 7 eastward moving systems as upper air cyclonic circulations in June, 7 in July, 10 in August and 6 in September.

**TABLE 8 (a)**

**Positions of Off-Shore Troughs During The Monsoon Period 2003**

| Date | Location | Date | Location |
|---|---|---|---|
| 6 Jun | Maharashtra to north Karnataka coasts | 13 – 14 Aug | Maharashtra to Kerala coasts |
| 7 – 8 Jun | Maharashtra to north Kerala coasts | 15 – 16 Aug | Maharashtra to Karnataka coasts |
| 9 – 11 Jun | Gujarat to Kerala coasts | 17 Aug | Karnataka to Kerala coasts |
| 12 – 15 Jun | North Maharashtra to Kerala coasts | 22 – 23 Aug | Karnataka to Kerala coasts |
| 16 – 21 Jun | South Gujarat to Kerala coasts | 27 Aug | Karnataka to Kerala coasts |
| 22 – 26 Jun | Maharashtra to Kerala coasts | 28 Aug | Maharashtra coast to Lakshadweep area |
| 27 – 30 Jun | South Gujarat to Kerala coasts | 29 Aug | Maharashtra to Karnataka coasts |
| 1 – 18 Jul | South Gujarat coast to Lakshadweep area | 30 Aug | Maharashtra coast to Lakshadweep area |
| 19 Jul | Karnataka to Kerala coasts | 31 Aug | Maharashtra to Kerala coasts |
| 20 Jul | South Maharashtra to Kerala coasts | 1 – 2 Sep | Karnataka to Kerala coasts |
| 21 Jul | Maharashtra to Karnataka coasts | 3 Sep | Gujarat to Karnataka coasts |
| 22 – 27 Jul | South Gujarat to Kerala coasts | 5 Sep | Maharashtra to Karnataka coasts |
| 28 – 29 Jul | South Gujarat coasts to Lakshadweep area | 6 Sep | Maharashtra to Kerala coasts |
| 30 Jul | South Gujarat to Karnataka coasts | 7 – 8 Sep | Maharashtra to Karnataka coasts |
| 31 Jul – 1 Aug | South Gujarat coasts to Lakshadweep area | 11 Sep | Maharashtra to Karnataka coasts |
| 2 – 3 Aug | South Maharashtra coast to Lakshadweep area | 16 – 17 Sep | Maharashtra to Karnataka coasts |
| 4 – 12 Aug | South Gujarat to Karnataka coasts | | |

**TABLE 8 (b)**

**Details of Off-shore trough from 1998-2003**

| Year | Details of off – shore trough |
|---|---|
| 2003 | Off-shore trough along different parts of west coast (surface and lower levels) observed upto 17 September from 6 June except during 18-21 August, 24-26 August, 4 September, 9-10 September and 12-15 September. |
| 2002 | Off-shore trough along different parts of west coast (surface and lower levels) observed upto 17 September except during 4-11 June, 25-31 July, 28-31 August and 14-16 September. |
| 2001 | Off-shore trough along different parts of west coast (surface and lower levels) noted upto 13 September except during 1-4 June and 11 September. |
| 2000 | Off-shore trough along different parts of west coast (surface and lower levels) persisted on most of the days (From 16 May to 4 September 2000), except for the periods 8-10 June, 16-25 June, 16 July – 7 August, 23-30 August. |
| 1999 | From 20 May to 22 September 1999, off-shore trough along different parts of west coast (surface and lower levels), persisted on most of the days except from 12 to 14, and from 16 to 26 August. |
| 1998 | From 16 June to 30 September, off-shore trough along different parts of west coast (surface and lower levels) persisted on most of the days except on 11 – 15 June, 18 – 19 July and 9 – 10 September. |

## 5. Extra Indian features

### 5.1. *Cross equatorial flow*

#### 5.1.1. *Over the Bay of Bengal*

Over Bay of Bengal, the cross equatorial flow was near normal (8-10 kts) during first two weeks of June and July and weaker than normal (8-10 kts) during later half of the months in June and July.

It was more than normal (8-10 kts) by 10-15 kts in the first two weeks and by about 5 kts in the second half of August.

In September 2003, the cross equatorial flow was more than normal (8-10 kts) by 10-15 kts in the first half and weaker than normal by about 3-5 kts in the second half of the month.

**TABLE 9**

**Statistics of mid latitude troughs**

| Level | June | July | August | September | Total |
|---|---|---|---|---|---|
| 300 hPa | 6 | 2 | 3 | - | 11 |
| 500 hPa | 7 | 5 | 4 | 3 | 19 |

5.1.2. *Over the Arabian sea*

It was nearly normal (10-12 kts) during June; more than normal (12-14 kts) by about 10 kts in July; more than normal(10-12 kts) by 5-10 kts in August except one week of weaker than normal by 3-5 kts and more than normal (8-10 kts) by 5-10 kts during entire September 2003.

5.2. *Mid-latitude troughs*

Monthwise break-up of troughs in westerlies found between 60° E – 90° E, reaching upto or south of 30° N is given in Table 9.

There were a total of 19 & 11 mid and upper tropospheric troughs respectively at 500 & 300 hPa during the season.

5.3. *Systems in west Pacific Ocean/south China Sea*

There were 12 systems (Tropical depression stage and above) in the northwest Pacific Ocean/ South China Sea during June – September 2003. The month wise break-up is shown in Table 10.

5.4. *Systems in southern hemisphere*

5.4.1. *Tropical storms*

Only one tropical storm formed (29 September to 2 October 2003) during the Southwest monsoon season, in South Indian Ocean.

5.4.2. *Mid and upper tropospheric westerly troughs over Indian Ocean*

There were a total of 15 upper air troughs in westerlies (6 in June, 3 in July, 4 in August & 2 in September) which moved across Indian Ocean from west to east to the north of Lat. 30° S, in the Southern Hemisphere during June to September 2003 (*Source*: INSAT full disc pictures).

**TABLE 10**

**Statistics of systems in West Pacific Ocean / South China Sea, Monsoon 2003**

| Weather systems | June | July | August | September | Total |
|---|---|---|---|---|---|
| T.D. | 0 | 0 | 1 | 0 | 1 |
| T.S. | 1 | 0 | 0 | 0 | 1 |
| Typhoon | 1 | 2 | 3 | 4 | 10 |
| Total | 2 | 2 | 4 | 4 | 12 |

5.4.3. *Mascarene high*

The intensity of Mascarene High at 30° S / 60° E was below normal in June and above normal in September. It was nearly normal in July and August but on the negative side. Source (Climate Diagnostic Bulletins, NOAA, June to September 2003, Departures are taken from the 1979 – 1995 base period monthly means). The intensity of Mascarene High along with that for the past 5 years, are given in Table 11.

5.4.4. *Australian high*

The intensity of Australian high pressure area at 30° S / 140° E was less than normal during August and September and nearly normal during June and July (Source: Climate Diagnostic Bulletins, June, July, August, September 2003, Departures are taken from the 1979 – 1995 base period monthly means). Details of the intensity of Australian High for the last five years are given in Table 12.

## 6. Semi-permanent systems

6.1. *Heat low*

The heat low over west Rajasthan and adjoining Pakistan at sea level formed on 22 May and was present on most of the days until 15 September. The lowest and

**TABLE 11**

**Intensity of Mascarene High during monsoon season for the years 1998 to 2003**

| Year | June | | July | | August | | September | |
|---|---|---|---|---|---|---|---|---|
| | Pressure (hPa) | Departure (hPa) | Pressure (hPa) | Departure (hPa) | Pressure (hPa) | Departure (hPa) | Pressure (hPa) | Departure (hPa) |
| 1998 | 1023 | -1 | 1026 | 3 | 1023 | -1 | 1024 | 0 |
| 1999 | 1023 | -1 | 1024 | 1 | 1024 | 0 | 1025 | 1 |
| 2000 | 1026 | 2 | 1022 | -2 | 1024 | 0 | 1023 | -1 |
| 2001 | 1023 | 0 | 1024 | -1 | 1028 | 2 | 1022 | -3 |
| 2002 | 1024 | 2 | 1027 | 1.5 | 1030 | 4 | 1024 | 0.5 |
| 2003 | 1023 | -1.5 | 1025.5 | -1 | 1026 | -1 | 1023.5 | 3 |

**TABLE 12**

**Intensity of Australian High during monsoon season for the years 1998 to 2003**

| Year | June | | July | | August | | September | |
|---|---|---|---|---|---|---|---|---|
| | Pressure (hPa) | Departure (hPa) | Pressure (hPa) | Departure (hPa) | Pressure (hPa) | Departure (hPa) | Pressure (hPa) | Departure (hPa) |
| 1998 | 1024 | 0 | 1024 | 0 | 1024 | 0 | 1023 | -1 |
| 1999 | 1029 | 5 | 1032 | 8 | 1032 | 10 | 1031 | 7 |
| 2000 | 1029 | 8 | 1024 | 4 | 1024 | 4 | 1024 | 5 |
| 2001 | 1020 | 2 | 1021 | 1 | 1019 | -1 | 1017 | -1 |
| 2002 | 1022 | 0 | 1022 | 0 | 1022 | 1.5 | 1017 | -1 |
| 2003 | 1022 | -1 | 1022 | 1 | 1020.5 | -1.5 | 1018 | -2 |

**TABLE 13**

**Details of lowest observed isobaric values of the heat low during the past 5 years**

| Month/year | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|
| June | 987.5 hPa (21) | 990 hPa (23) | 989 hPa (13, 14, 16 &25) | 987.0 hPa (20 & 21) | 988 hPa (21 & 22) |
| July | 985.6 hPa (12) | 988 hPa (2) | 989 hPa (7) | 989 hPa (12) | 988 hPa (2) |
| August | 990.7 hPa (4) | 988.5 hPa (6) | 990 hPa (30) | 990 hPa (29) | 998 hPa (11) |
| September | 993.9 hPa (3) | 994.0 hPa (17) | 992 hPa (1) | 995 hPa (5 & 10) | 997 hPa (4) |

the second lowest observed pressure values of the heat low were :

June : 986 hPa (on 7, 8 & 27) and 988 hPa (on 6, 11, 15 & 23)

July : 990 hPa (on 4, 9 & 30) and 991 hPa (on 8, 24, 25 & 31)

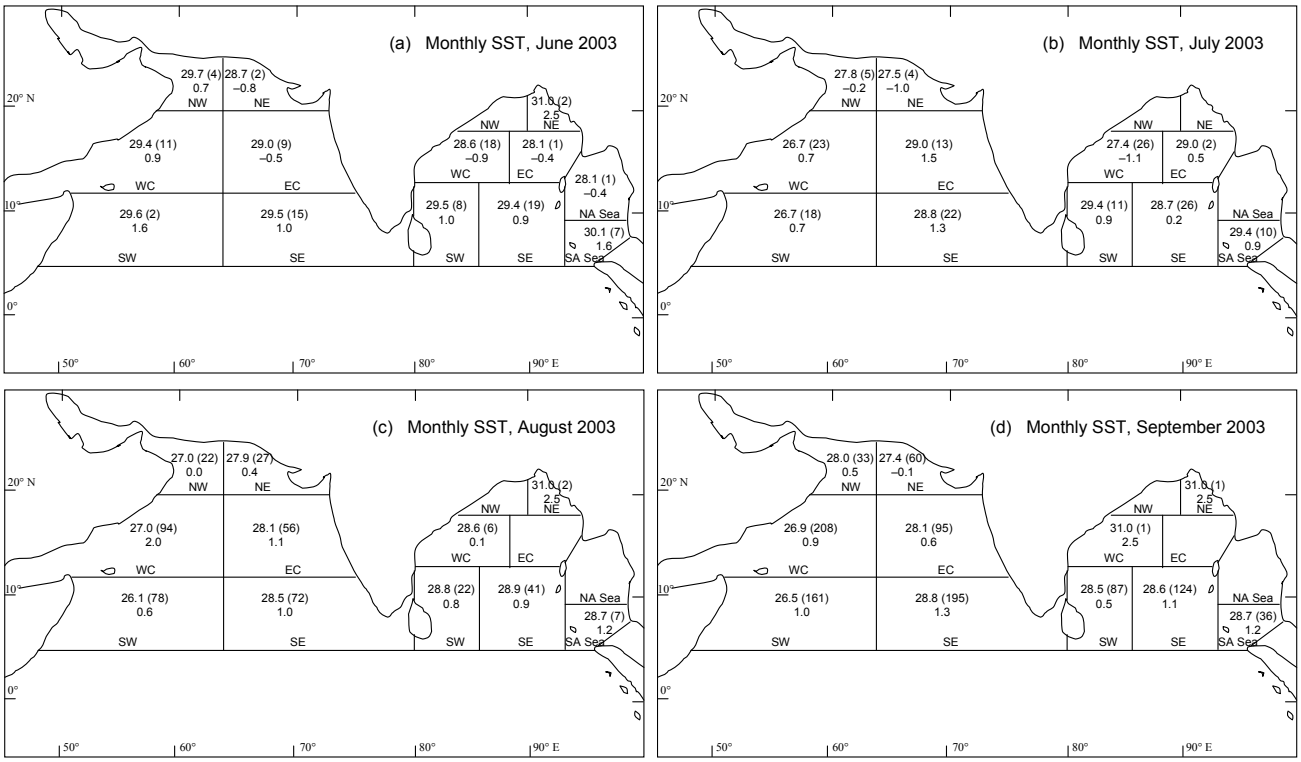
August : 991 hPa (on 9) and 992 hPa (on 3 & 18)

September : 993 hPa (on 2) and 994 hPa (on 3)

Details of the lowest observed isobaric values of the Heat Low during past five years are given in Table 13.

### 6.2. *Axis of the monsoon trough*

Monsoon trough got established quite south of its normal position on 5 July. Thereafter it remained more or less in its normal position until 16 September with the exception that the western end shifted north of it's normal position, towards the end of July, during mid August and also in the beginning of September. There were no breaks or break like situations during this season, with the eastern end of the monsoon trough occupying either normal or south of it's normal position throughout the period.




**Figs. 10(a-d).** SST and SST anomaly in (°C). The numbers inside the brackets indicate the number of observation

For ready comparison, the positions of monsoon trough in the past five years are given below.

| *Year* | *Axis of Monsoon Trough* |
|---|---|
| 1998 | Established on 21 June. Less marked on 23 September Break from 16 to 26 July and 20 to 26 August. |
| 1999 | Established on 10 June. Less marked on 26 September. |
| 2000 | Established on 2 July. Less marked on 22 September. Break from 1 – 4 August. |
| 2001 | Established on 3 July. Less marked on 20 September. |
| 2002 | Established on 15 August and less marked on 16 September. |

### 6.3. *Tibetan anticyclone/high*

Tibetan anticyclone (TA) was established at 500, 300 & 200 hPa levels on 15 June. It was seen around its normal position at 300 & 200 hPa (while being absent at 500 hPa on many occasions during June and first half of July) until 14 September. During August, it was seen east of its normal position on most of the days, at all the 3 levels. The details of Tibetan Anticyclone for the past five years are given below.

| *Year* | *Tibetan Anticyclone* |
|---|---|
| 1998 | Appeared on 13 June. Less marked on 27 September. |
| 1999 | Appeared on 10 June. Seen on most of the days during July, August & September. |
| 2000 | Appeared on 5 June. |
| 2001 | Established on 12 June. Not seen in last week of August. Less marked on 13 September. |
| 2002 | Established on 15 June. Not seen at 500 hPa during June & first half of July. Less marked on 14 September. |

### 6.4. *Sub-Tropical Westerly Jet (STWJ)*

STWJ was seen over Srinagar on 5 June and over Delhi on 25 June. It then shifted northwards and re-appeared over Jodhpur, Gwalior and Delhi on 1 October.

The days, the Sub tropical Westerly Jet was observed in the past five years are given below.

| *Year* | *Sub-Tropical Westerly Jet (STWJ)* |
|---|---|
| 1998 | Seen only in first week of June. |
| 1999 | Seen only till 12 June. |
| 2000 | Made appearances on 5 June, 24 June & 16 July and re-appeared in the last week of September. |
| 2001 | Seen over north India during last week of May and reappeared in last week of September. |
| 2002 | Seen over north India during first week of June and reappeared in the last week of September. |

### 6.5. *Tropical Easterly Jet (TEJ)*

TEJ was observed over Minicoy from 7 June to 15 September. The maximum wind reported was, 125 kts. at 116 hPa at 1200 UTC of 25 July. It was seen over Thiruvananthapuram from 9 May to 25 September. Maximum wind speed of 100 kts were observed on many occasions *viz*., 21 & 27 June, 16 July around 120 hPa. Over Chennai, it's continuous appearance was from 8 June and was noticed upto 21 September. Here also, a maximum wind speed of 100 kts was reported at 119 hPa at 1200 UTC of 14 July. Over Port Blair TEJ appeared on 26 May to 15 September, with a maximum wind speed of 85kts reported at 1200 UTC of 9 July (134 hPa).

It's appearance over Mumbai was much delayed. It was seen from 29 June to 15 September and the maximum wind speed noticed was, 105 kts at 0000 UTC of 29 June at 117 hPa level.

Very often easterly winds of jet speed were reported over Visakhapatnam, Nagpur, Kolkata, Bhubaneswar etc. latitudes as well, in 100 – 150 hPa levels.

Above observations indicated that TEJ was split up and seen over Guwahati latitude in the month of July. Details of TEJ in the past five years are as follows.

| *Year* | *Tropical Easterly Jet (TEJ)* |
|---|---|
| 1998 | Appeared from 1st week of June till the end of September Max. wind 150 kts over MNC at 103 hPa on 5 August. |
| 1999 | Appeared on 3 June till the end of September Maximum wind 140 kts at 141 hPa on 28 July. |
| 2000 | Seen from 1st week of June, till the end of September. Maximum wind speed 155 kts at 177 hPa on 6 September. |
| 2001 | Seen from 24 May, till 15 September. Maximum wind speed 150 kts at HYD at 115 hPa on 21 July. |
| 2002 | Seen from 7 June, till end of September. Maximum wind speed 105 kts at 137 hPa over Chennai on 18 June. |

## 7. Sea surface temperature (SST)

Monthly mean SST values for June, July, August and September 2003 for Arabian Sea, Bay of Bengal as well as Andaman Seas are discussed below. The same is presented in pictorial form [Figs. 10(a-d)] also. Map showing the four months SST anomalies in each block is also given.

The normal values for each sector for calculating the anomalies have been estimated from the normal isotherms. (Climatic Atlas of the Indian Ocean, Part I by Stephen Hastenrath and Peter J. Lamb.)

The main features of monthly SSTs are given below:

### 7.1. *June*

Except NE and EC sectors of Arabian Sea, $SST_s$ over the remaining sectors (SW, WC, NW and SE) were warmer than normal with the highest positive anomaly of 1.6° C in SW Sector. Southern Bay (SW and SE sectors), NE Bay and south Andaman Sea were warmer than normal. While WC, EC sectors of Bay and north Andaman Sea regions were cooler than normal.

### 7.2. *July*

Except NW and NE Sectors of Arabian Sea, $SST_s$ over WC, EC, SW and SE sectors of Arabian Sea were warmer than normal with the highest positive anomaly of 1.5° C in EC Sector. Similarly, except WC sector of Bay, SSTs over EC, SW and SE Sectors of Bay were warmer than normal. South Andaman Sea had the anomaly of 0.9° C during the month.

### 7.3. *August*

$SST_s$ over all sectors of Arabian Sea were warmer than normal with the highest anomaly of 2.0° C over WC Arabian Sea. SSTs over all available sectors of Bay (WC, SW and SE) were also warmer than normal. South Andaman Sea was warmer than normal by 1.2° C.

### 7.4. *September*

Except NE Sector of Arabian Sea, SSTs over all remaining sectors (NW, WC, EC, SW and SE) were warmer than normal with highest anomaly being 1.3° C over SE sector of Arabian Sea.

SSTs over all available sectors of Bay (NE, WC, SW and SE) were warmer than normal with highest anomaly being 2.5° C over WC Bay. South Andaman Sea was warmer than normal by 1.2° C.

**TABLE 14**

**Zonal wind anomaly (June to September 2003)**

| Week ending dates | 30 Jun | 10 Jun | 17 Jun | 24 Jun | 1 Jul | 8 Jul | 15 Jul | 22 Jul | 29 Jul | 5 Aug | 12 Aug | 19 Aug | 26 Aug | 2 Sep | 9 Sep | 16 Sep | 23 Sep | 30 Sep |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Thiruvananthapuram (TRV)** | | | | | | | | | | | | | | | | | | |
| 850 | -1.5 | -2.6 | -2.4 | 2.9 | -1.3 | -1 | -6 | -7 | -0.6 | -13.2 | -4.9 | -7.5 | -2.2 | -6.8 | -8.7 | -6 | -7.4 | -8.4 |
| 500 | -4.9 | -9.3 | -9.8 | -2.6 | -8.5 | -4.4 | -6.1 | -5.4 | 4.4 | -1.1 | -8.4 | -3.7 | -9.4 | -1.7 | -6 | 7.6 | -3.8 | -7.5 |
| 200 | 5 | -8 | -2 | 9.1 | -5.9 | 12.7 | 5.9 | 5.4 | 5.1 | 9.6 | -3.8 | 7.5 | -3.5 | 5.7 | -4.7 | -6 | -5.3 | -0.3 |
| **Chennai (MDS)** | | | | | | | | | | | | | | | | | | |
| 850 | -0.3 | -2.3 | 4.3 | 9.9 | -4.6 | 0.4 | -3 | -6.3 | 4.1 | -5.6 | 3 | 1.7 | 11.9 | 2 | 5.5 | 6.4 | 2.8 | 3.4 |
| 500 | -8.9 | -4 | -2.4 | -2.2 | 1.2 | -4.2 | -4.9 | 5 | 8.5 | 1.3 | 0.5 | -12.6 | 8.2 | 4.2 | 0.4 | 7 | -4.6 | -7.7 |
| 200 | -3.8 | -6.6 | -8.5 | 8.9 | | -1.5 | 3 | 13.1 | 1 | 9.4 | 1.1 | -3.8 | 7 | 6.8 | -1.3 | -8.3 | -4.3 | 3.3 |
| **Mumbai (BMB)** | | | | | | | | | | | | | | | | | | |
| 850 | -1.4 | -0.7 | -6.3 | 0.8 | -0.9 | -5.4 | -7.2 | -5.7 | 2.6 | 1.2 | -2.6 | -0.1 | -2.7 | 7 | 6.1 | 6.5 | 4.6 | 0.2 |
| 500 | 7.4 | -13 | -4.8 | | 0.7 | -6.4 | -6.3 | -2.5 | 9.2 | -0.8 | 3.1 | 0.1 | -2.6 | 5.7 | 1.7 | -3.3 | -2.8 | 3.8 |
| 200 | 28.4 | 8.8 | | | -3.4 | -1.8 | -2.9 | 7.3 | 7.3 | 11 | 7.5 | -9.3 | 3.5 | -0.3 | -5 | -1.5 | -7.3 | -0.3 |
| **Nagpur (NGP)** | | | | | | | | | | | | | | | | | | |
| 850 | 3.7 | 8.5 | 3.5 | 7.2 | 7.3 | -3.1 | -3.8 | -10.2 | 7.5 | 1 | -17.2 | 6 | 4.2 | -5.3 | 14.9 | 11 | 1.6 | 0.8 |
| 500 | 11.5 | -4.2 | 0.2 | | | | | | | | -12.7 | | | 12.3 | | -0.7 | -1 | -8.8 |
| 200 | 6.4 | 24.5 | 14.3 | | | | | | | | | | | | | -42.3 | -44.1 | |

Note : 1. Easterly anomalies (-ve) at 850 hPa means that westerlies are weaker than normal.
2. Westerly anomalies (+ve) at 200 hPa means that easterlies are weaker than normal.
3. Blank space ’means no data.

From the above discussion it is seen that WC, SW and SE sectors of Arabian Sea were warmer than normal throughout the season. Again except during June, EC sector of Arabian Sea was also warmer than normal during July to September. All sectors of Bay and South Andaman Sea was warmer than normal during August and September. During June and July, Southern Bay (SW and SE sectors) and south Andaman Sea were warmer than normal.

## 8. Other features

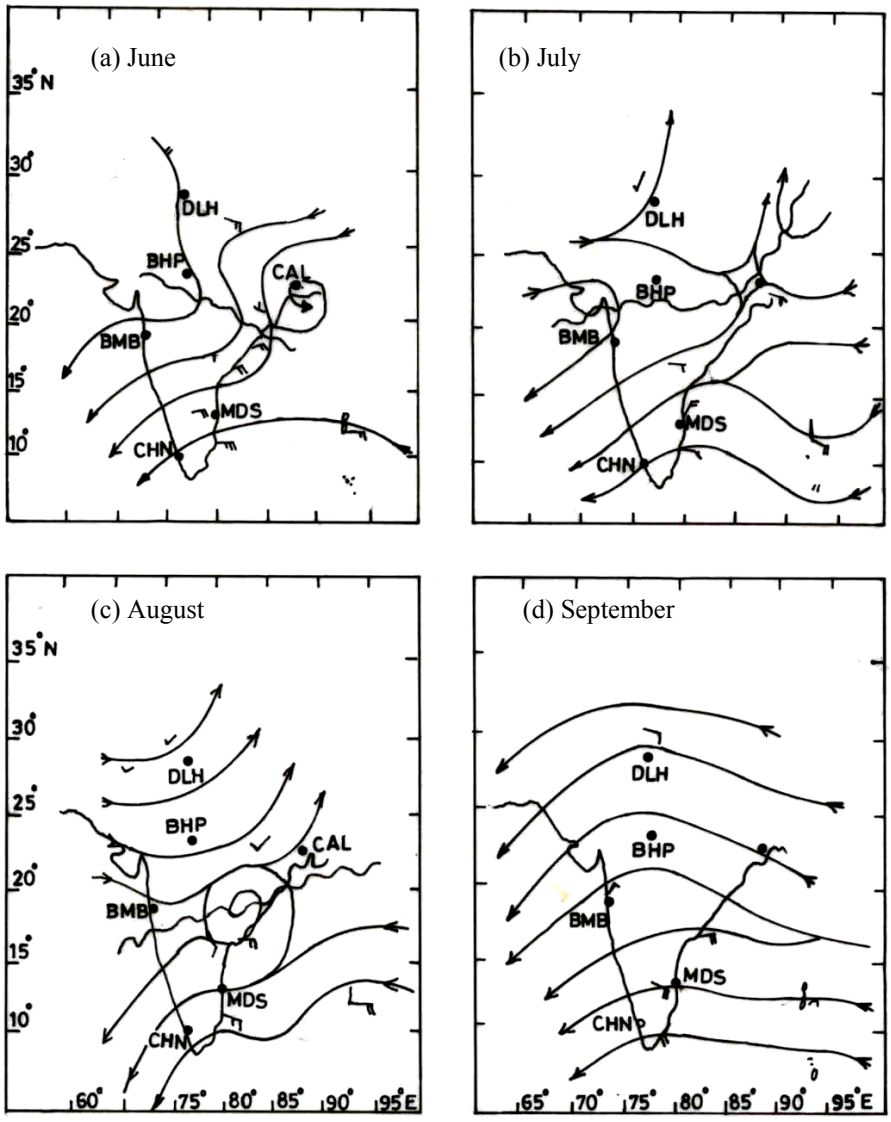
### 8.1. *Weekly upper wind anomalies in monsoon 2003*

The circulation anomaly features during the monsoon season (June-Septemeber) 2003 are discussed below as noticed from the Monthly & Weekly wind vector anomalies at 850, 500 and 200 hPa levels. Also the zonal wind anomalies observed at four different stations over the Peninsula are given in Table 14.

#### 8.1.1. *June wind anomaly features*

The monthly wind at 850 hPa indicated southerly anomalies over the Bay of Bengal and Peninsular region south of 20° N. At 200 hPa level, ridge was located around 25° N and no intrusion of mid latitude westerlies over India upto 30° N.

The circulation pattern for the week ending on 3 June at lower and middle troposphere upto 500 hPa levels was characterised by northerly/northeasterly anomaly over southern peninsula indicating a weak monsoon. In the subsequent week (for the week ending 10 June) was associated with an anomalous E-W ridge over the peninsular India extending upto middle troposphere indicating a weak monsoon. The upper level easterly was also weaker than normal during the week. For the week ending 17 June there was an anomalous cyclonic circulation over Maharashtra and Karnataka coast at lower tropospheric levels associated with stronger monsoon condition over the region. But southern tip of the country was associated with an anomalous anticyclone with weaker monsoon condition over the region. In the last week of June, for week ending 24, there existed an anomalous cyclonic circulation at southern tip of India and northern part of the country at lower tropospheric levels associated with stronger monsoon condition.




**Figs. 11(a-d).** Anomalous wind flow during monsoon 2003 at 30 hPa

8.1.2. *July wind anomaly features*

The monthly wind at 850 hPa indicated southerly anomalies over the Bay of Bengal and Peninsular region and southeasterly anomalies were noticed over the Arabian Sea.

In the week ending on 1 July, there existed anomalous anticyclone associated with E-W ridge at lower tropospheric levels over peninsular India with weaker monsoon condition. The week ending 8 July was associated with anomalous E-W trough along 15° N and anomalous ridge over southern tip of the country at lower tropospheric levels. The upper level easterlies were weaker than normal at southern tip of the country during the week. For week ending 15 July there existed an anomalous E-W ridge along 20° N with weaker than normal southwesterly wind over central India at lower and middle troposphere. However, anomalous cyclonic circulation was observed at southern tip of India at lower levels. During the week ending on 22 July same feature continued from the last week with anomalous ridge over northern part and anomalous trough over the Central India. In the last week of July for week ending 29, the pattern of previous week just reversed with anomalous ridge over southern part of India and anomalous E-W

trough over the northern part of the country at lower and middle tropospheric levels.

8.1.3. *August wind anomaly features*

The monthly wind at 850 hPa indicated easterly/southeasterly anomalies over the Arabian Sea with anomalous anticyclonic flow over the west coast region.

During the first week of August ending on 5 there existed an anomalous cyclonic circulation over the Bay of Bengal and adjoining NE India at lower and middle troposphere. On the other hand Central India was associated with anticyclonic flow at lower tropospheric levels. The upper level easterly was weaker than normal during the week. During the week ending on 12, the pattern slightly changed with the appearance of an anomalous cyclonic circulation and associated E-W trough over central India. On week ending 19, there existed an anomalous E-W trough over the northern part of the country at lower and middle troposphere. Whereas over Central India it was associated with anomalous anticyclone with E-W ridge. The upper level easterly was weaker than normal during the week. In the week ending on 26, the pattern changed from previous week and anomalous E-W trough prevailed over Central India at lower and middle troposphere associated with stronger monsoon condition over the region.

8.1.4. *September wind anomaly features*

The monthly wind at 850 hPa indicated an anomalous anticyclonic flow over the southern Peninsula and adjoining area.

During the first week of September ending on 2, anticyclonic flow associated with anomalous ridge prevailed over Central and Southern parts of country at lower and middle troposphere indicating weak monsoon condition. Northern and eastern parts of the country was characterised by anomalous cyclonic circulation and anomalous E-W trough at lower and middle troposphere during the week. The same condition prevailed in subsequent week ending on 9 also. During the week ending on 16 an anomalous ridge prevailed at lower troposphere over southern part of the country indicating weaker monsoon condition over the region. Over Orissa and Gangetic West Bengal an anomalous cyclonic circulation prevailed in the lower levels. During the subsequent week ending on 23, anomalous cyclonic flow prevailed over Central India over Gujarat and Maharashtra Coast in the lower levels with anomalous anticyclonic flow over southern parts of the country. Similar to the previous week, during the last week of September ending on 30 also, anomalous anticyclonic flow continued to prevail over the southern parts of the country.

8.2. *Stratospheric features*

8.2.1. *Winds at 10 hPa*

For the monsoon season 2003, stratospheric wind data were not available for the level 10 hPa level. Therefore only wind data at 30 hPa were considered. The monthly stratospheric wind data at 30 hPa from all the available RS stations were analysed.

8.2.2. *Winds at 30 hPa*

Fig. 11 shows the monthly anomalous flow patterns at 30 hPa for June to September. It can be seen that during the first three months (June to August), there was an anomalous ridge along 20° N. This indicates that over the region south of 20° N, the stratospheric wind anomalies were easterlies and stronger than normal. During September, entire region was under the easterly anomaly regime. The above feature of stratospheric wind anomalous flow at 30 hPa during the monsoon season 2003 was opposite to that observed during the monsoon season 2002 when the wind anomalies over the region south of 10° N was persistently westerlies.

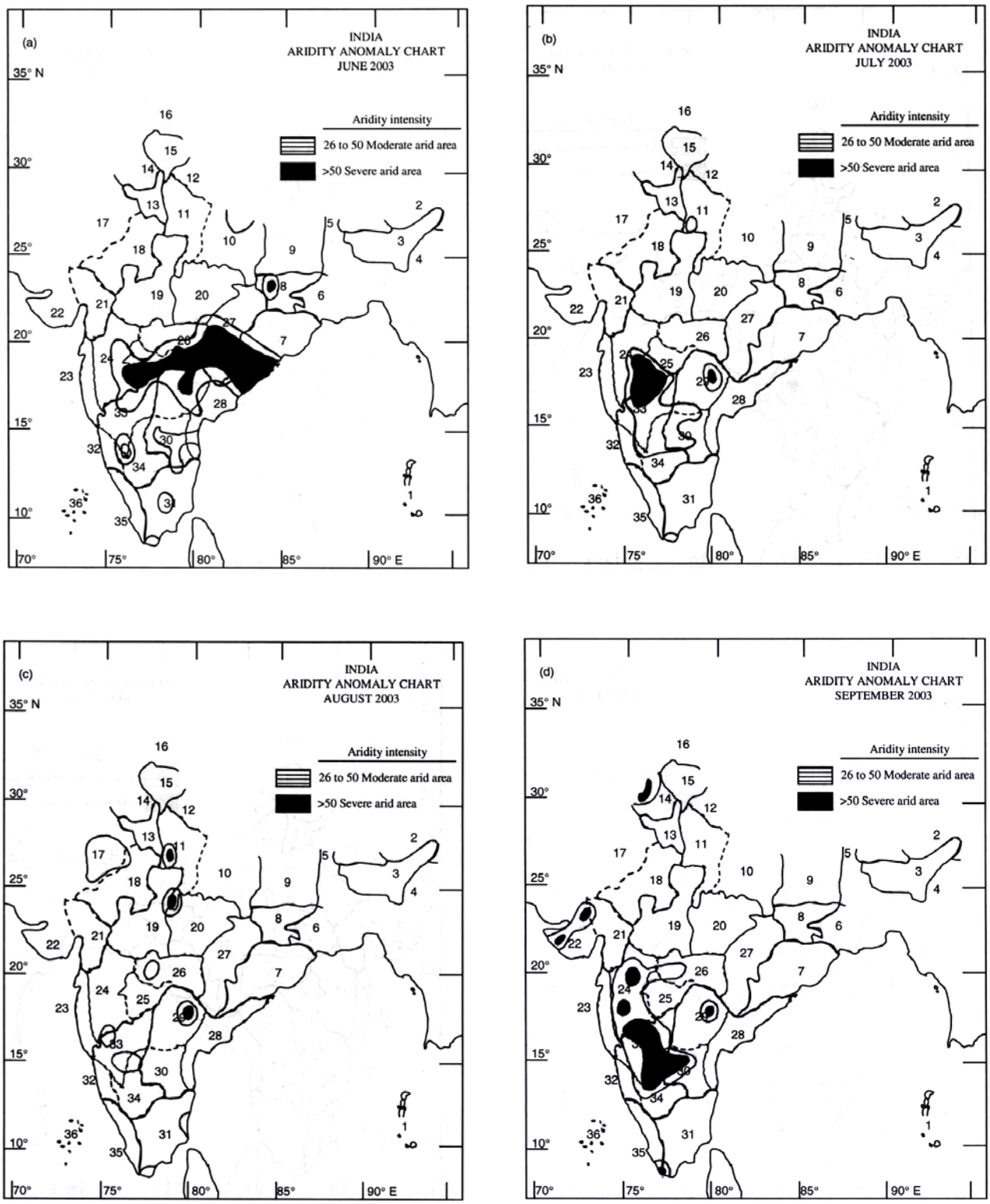
8.3. *Aridity conditions during monsoon 2003*

Aridity Index (AI) is computed based on Thornthwaite's formula :

$$AI = \frac{PE - AE}{PE} \times 100$$

Where, PE is potential evapotranspiration, which is nothing but the loss of water vapour to atmosphere in the form of evaporation from soil, and transpiration from the plants, when the supply of water is unlimited. This is water need of the plants. AE denotes the Actual Evapotranspiration and PE – AE denotes the water deficiency. PE is computed by Penman's modified equation and AE is obtained from the water balance procedure, which takes into account the water holding capacity of the soil.

The difference between actual Aridity for the month and normal aridity *i.e.* the aridity anomaly is worked out.




**Figs. 12(a-d).** Aridity anomaly chart for the month (a) June 2003, (b) July 2003 (c) August 2003 and (d) September 2003

Aridity of a particular region is decided based on the aridity anomalies, which have been classified as follows :

| *Aridity Anomaly* | *Class* |
|---|---|
| 0 or less | Non-Arid |
| 1 to 25 | Mild Arid |
| 26 to 50 | Moderate Arid |
| More than 50 | Severe Arid |

Aridity Anomaly maps for June, July, August and September is given in Figs. 12 (a-d) respectively.

Moderate to severe arid conditions were noticed in northern and small eastern parts of the peninsula in June. In July these areas in eastern parts of peninsula had decreased and those in west central parts of peninsula increased. In August the moderate and severe arid areas in peninsula decreased to some small isolated patches but small moderate and severe arid area appeared in northwestern parts of the country. These areas in the northwestern parts decreased and increased in western parts of peninsula in September.

Severe and moderate arid conditions which prevailed over the country during the monsoon months are given below:

8.3.1. *June*

(a) *Severe arid areas*

(*i*) Large areas of Orissa, Chattisgarh and Vidarbha.

(*ii*) Small areas in northern parts of coastal Andhra Pradesh; northeastern parts of Telangana; southeastern, northeastern and western parts of Marathwada and southeastern parts of Madhya Maharashtra.

(*iii*) Isolated areas around Daltonganj (Bihar) and Shimoga (south interior Karnataka)

(b) *Moderate arid areas*

(*i*) Small areas in central and southern parts of Orissa; central and southern parts of Chattisgarh; southern parts of east Madhya Pradesh; northeastern, central and southwestern parts of Vidarbha; northeastern, western, eastern and southern parts of Marathwada; eastern parts of Madhya Maharashtra; northwestern parts of north interior Karnataka; northern, central and eastern parts of Telangana; central, western and southern parts of coastal Andhra Pradesh; eastern, central and southern parts of Rayalaseema; northwestern parts of Tamil Nadu; western parts of south interior Karnataka; western parts of Jharkhand and northwestern parts of east Uttar Pradesh.

(*ii*) Isolated areas around Udaipur (east Rajasthan), Sagar (east Madhya Pradesh), Madurai and Kanyakumari (Tamil Nadu).

8.3.2. *July*

(a) *Severe arid areas*

(*i*) Small areas in eastern and southern parts of Madhya Maharashtra and western and southern parts of Marathwada.

(*ii*) Isolated areas around Hanamkonda (Telangana) and Shimoga (south interior Karnataka).

(b) *Moderate arid areas*

(*i*) Large parts of north interior Karnataka and south interior Karnataka.

(*ii*) Small areas in central, eastern and southern parts of Madhya Maharashtra; western and central parts of Marathwada; northwestern and western parts of Rayalaseema; southern and central parts of Telangana.

(*iii*) Isolated area around Agra (west Uttar Pradesh); Akola and Gondia (Vidarbha) and Kanyakumari (Tamil Nadu).

8.3.3. *August*

(a) *Severe arid areas*

(*i*) Small areas of western parts of west Uttar Pradesh.

**TABLE 15**

**Extreme rainfall amounts over the country during June-September 2003**

| Date | Rainfall amount (cms) and Station (Met. sub-division) |
|---|---|
| (1) | (2) |
| 8 Jun | 26 – Cherrapunji (Assam & Meghalaya) |
| 9 Jun | 32 – Cherrapunji (Assam & Meghalaya) |
| 10 Jun | 184 – Cherrapunji, 29 – Amraghat (Assam & Meghalaya) |
| 12 Jun | 56 – Cherrapunji (Assam & Meghalaya) |
| 13 Jun | 86 – Cherrapunji, 29 – Aba NH Xing. (Assam & Meghalaya) |
| 16 Jun | 26 – Murbad (Konkan & Goa) |
| 19 Jun | 21 – Matheran, 20 – Panvel (Konkan & Goa) |
| 20 Jun | 29 – Sundergarh, 27 – Thakurmunda, 22 – Jharsuguda (Orissa)<br>20 – Panjim (Konkan & Goa)<br>20 – Karwar (coastal Karnataka) |
| 21 Jun | 32 – Navsari, 23 – Bardoli, 21 – Gandevi, (Gujarat Region)<br>27 – Mahabaleshwar (Madhya Maharashtra)<br>25 – Poladpur, 24 – Murbad, Mandangad (Konkan& Goa)<br>20 – Mangalore (coastal Karnataka) |
| 22 Jun | 39 – Ankola, 33 – Panambur, 31- Manki, 30 – Mangalore, 29 – Kota, Udupi, Kumta, 28 – Mulki, 27 – Jagalpet, 25 – Gokarna, 24 – Mudibidre, Bantwal, Honavar, Joida, 23 – Kundapura, 21 – Kollur, 20 - Shirali, Karwar. (coastal Karnataka)<br>38 – Chandgad, 22 – Gargoti (Madhya Maharashtra)<br>37 – Songadh (Gujarat Region)<br>33 – Cherrapunji. (Assam & Meghalaya)<br>30 – Khed (Konkan)<br>24 – Kasargod (Kerala)<br>21 – Londa, Khanapura (north interior Karnataka) |
| 23 Jun | 32 Kollur (coastal Karnataka), Agumbe, Kollur (north interior Karnataka), 28 – Sringeri, 24 – Linganamakki (south interior Karnataka)<br>21 – Mahabaleshwar (Madhya Maharashtra) |
| 24 Jun | 35 – Saulighat, 21 – Sonbarsa (Bihar)<br>21 – Bantwal (coastal Karnataka) |
| 26 Jun | 26 – Sabroom (Nagaland-Manipur-Mizoram-Tripura) |
| 28 Jun | 21 – Basti (east Uttar Pradesh)<br>21 – Kalyan (Konkan & Goa) |
| 29 Jun | 26 – Cherrapunji (Assam & Meghalaya)<br>23 – Belonia (Nagaland-Manipur-Mizoram-Tripura) |
| 30 Jun | 26 – Jowai (Assam & Meghalaya) |
| 1 Jul | 29 – Gajoldoba, 21 – Neora, 20 – Domohani, Hasimara, Nagrakata, Murti (Sub-Himalayan West Bengal & Sikkim) |
| 4 Jul | 26 – Alipurduar, 24 – Domohani, 22 – Jalpaiguri (Sub-Himalayan West Bengal & Sikkim) |
| 5 Jul | 21 – Mahuva (Saurashtra & Kutch),<br>20 – Cherrapunji (Assam & Meghalaya)<br>20 – Chatia (Bihar)<br>20 – Paonta (Himachal Pradesh) |
| 7 Jul | 35 – Chepan, 28 – Alipurduar (Sub-Himalayan West Bengal & Sikkim) 31 – Passighat (Arunachal Pradesh) |
| 8 Jul | 31 – Passighat (Arunachal Pradesh)<br>27 – Gajoldoba, 25 – Hasimara, 23 – Nagrakata, 22 – Diana (Sub-Himalayan West Bengal & Sikkim),<br>26 – Murti (Assam & Meghalaya)<br>21 – Kalyanpur (Saurashtra & Kutch) |
| 11 Jul | 27 – Bharatpur (east Rajasthan)<br>23 – Cherrapunji (Assam & Meghalaya)<br>21 – Hapur, Mathura (west Uttar Pradesh) |
| 12 Jul | 21 – Najibabad, 20 – Muradabad, Chatnag (west Uttar Pradesh) |

**TABLE 15 (*Contd*.)**

| (1) | (2) |
|---|---|
| 13 Jul | 21 – Belonia (Nagaland-Manipur-Mizoram-Tripura) |
| 15 Jul | 20 – Bhandup (Konkan & Goa) |
| 20 Jul | 25 – Cherrapunji (Assam & Meghalaya) |
| 25 Jul | 37 – Lanji (east Madhya Pradesh)<br>25 – Mundra (Saurashtra & Kutch)<br>25 – Korba (Chattisgarh) |
| 26 Jul | 25 – Kendrapara, 20 – Soro (Orissa) |
| 27 Jul | 24 – Shahuwadi, 21 – Mahabaleshwar (Madhya Maharashtra)<br>23 – Ambabhona (Orissa) |
| 28 Jul | 35 – Navsari, Gandevi, 29 – Ahwa, 27 – Mahuwa, Vyara, 26 – Surat, 24 – Valod, Madhuban, Vijapur, 23 – Mehsana, 22 – Dharampur, 21 – Palsana, Chikhali, 20 – Songarh, Visnagar, Banda. (Gujarat Region)<br>35 – Jawhar, 31 – Panvel, 25 – Mokhada, Karjat, 22 – Dahanu, Wada (Konkan & Goa)<br>27 – Banswara, 20 – Kushalgarh (east Rajasthan)<br>22 – Peint (Madhya Maharashtra) |
| 30 Jul | 29 – Cherrapunji (Assam & Meghalaya) |
| 31 Jul | 20 – Rewaghat. (Bihar)<br>25 – Bangana, 22 – Nadaun, 20 – Barsar (Himachal Pradesh) |
| 1 Aug | 28 – Dharamsala, 20 – Baijnath (Himachal Pradesh),<br>20 – Konni (Kerala). |
| 6 Aug | 21 – Navsari (Gujarat Region) |
| 7 Aug | 29 – Jamnagar, 27 – Kodinar, 20 – Keshod (Saurashtra & Kutch) |
| 17 Aug | 20 – Cooch Behar (Sub-Himalayan West Bengal & Sikkim) |
| 21 Aug | 24 – Jammu (Jammu)<br>24 – Aurad, 21 – Bidar (north interior Karnataka) |
| 24 Aug | 24 – Nadiad, 20 – Ahmedabad, Wanakbori (Gujarat Region) |
| 25 Aug | 29 – Viramgarh, 28 – Kadi, 23 – Kalol. (Gujarat Region) |
| 27 Aug | 34 – Jaipatna (Orissa) |
| 28 Aug | 26 – Bijepur, 24 – Baliguda, 23 – Ambabhona, 22 – Paikmal,<br>21 – Patnagarh, Belgaon, Kantamal, 20 – Tikabali, Titlagarh. (Orissa) |
| 29 Aug | 20 – Jhajgir (Chattisgarh) |
| 30 Aug | 21 – Pushkar (east Rajasthsn) |
| 1 Sep | 28 – Galgalia. (Bihar) |
| 3 Sep | 21 – Ambala (Haryana), 21 – Nahan. (Himachal Pradesh) |
| 6 Sep | 32 – Bolangir, Baliguda, 28 – Kotagharh (Orissa ),<br>30 – Sitapur, 21 – Hasanganj (east Uttar Pradesh) |
| 7 Sep | 24 – Sikohabad, (west Uttar Pradesh), 23 – Sakti. (Chattisgarh) |
| 9 Sep | 20 – Satna (east Madhya Pradesh) |
| 11 Sep | 24 – Hardwar, 22 – Mainpuri (west Uttar Pradesh) |
| 16 Sep | 28 – Sharadanagar (east Uttar Pradesh) |
| 20 Sep | 20 – Jalpaiguri (Sub-Himalayan West Bengal & Sikkim) |
| 30 Sep | 21 – Jaunpur (east Uttar Pradesh) |

(*ii*) Isolated areas around Sikar (east Rajasthan), Jhansi (west Uttar Pradesh), Hanamkonda (Telangana) and Sangli (Madhya Maharashtra).

(b) *Moderate arid areas*

(*i*) Large areas of Jammu & Kashmir.

(*ii*) Small areas of eastern and central parts of west Rajasthan and adjoining northwestern and eastern parts of east Rajasthan; western and southern parts of west Uttar Pradesh and adjoining eastern parts of east Rajasthan; eastern parts of Gangetic West Bengal and adjoining southern parts of sub-Himalayan West Bengal; central parts of Telangana; southeastern parts of Madhya Maharashtra and northwestern and southeastern parts of north interior Karnataka; northern parts of south interior Karnataka and adjoining parts.

(*iii*) Isolated areas around Cooch Behar (Sub-Himalayan West Bengal), Akola (Maharashtra), Machilipatnam – Kakinada (coastal Andhra Pradesh), Chikmangalur (south interior Karnataka), Kanyakumari and Nagapattinam (Tamil Nadu).

8.3.4. *September*

(a) *Severe arid areas*

(*i*) Large areas of north interior Karnataka and south interior Karnataka.

(*ii*) Small areas of southeastern parts of Madhya Maharashtra and northwestern parts of Rayalaseema.

(*iii*) Isolated areas around Amritsar (Punjab); Jamnagar (Saurashtra & Kutch); Radhanpur (Gujarat); Pune and Malegaon (Madhya Maharashtra); Hanamkonda (Telangana) and Thiruvananthapuram (Kerala).

(b) *Moderate arid areas*

(*i*) Large areas of Madhya Maharashtra.

(*ii*) Small areas of northwestern parts of Punjab; western and northeastern parts of Saurashtra & Kutch and adjoining northwestern parts of Gujarat Region; western parts of Vidarbha; northern and northeastern parts of Marathwada; southwestern and central parts of north interior Karnataka, western and central parts of south interior Karnataka; northern and southwestern parts of Rayalaseema; eastern parts of Telangana; southwestern parts of Tamil Nadu and southern parts of Kerala.

(*iii*) Isolated areas around Sabour (Bihar), Jaipur (east Rajasthan), Cuddalore and Madurai (Tamil Nadu).

## 9. Significant spells of heavy rains

Amounts of heavy and very heavy rainfall are given in Table 15 and the spatial distribution of *heavy* and *very heavy* rainfall is given in Table 16. Table 16 also indicates the *activity* of monsoon and sub-divisionwise extent of rainfall in number of days when it was *widespread* or *fairly widespread*. Monthwise description is given below :

9.1. *Heavy rainfall during June*

During the month, *very heavy* rainfall occurred on 10 to 12 days in Assam & Meghalaya and Konkan & Goa; on 4 to 7 days in Nagaland-Manipur-Mizoram-Tripura, Sub-Himalayan West Bengal & Sikkim, Bihar, Gujarat Region, coastal Karnataka and Kerala and on 1 to 3 days in Arunachal Pradesh, Gangetic West Bengal, Orissa, east Uttar Pradesh, west Madhya Pradesh, Saurashtra & Kutch, Madhya Maharashtra, north interior Karnataka and Lakshadweep. *Heavy* rainfall also occurred on 4 to 7 days in Arunachal Pradesh, Assam & Meghalaya, Sub-Himalayan West Bengal & Sikkim, Gangetic West Bengal, Haryana, Madhya Maharashtra, coastal Karnataka and on 1 to 3 days in Nagaland-Manipur-Mizoram-Tripura, Orissa, Bihar, Uttar Pradesh, Uttaranchal, Himachal Pradesh, east Rajasthan, Madhya Pradesh, Gujarat State, Konkan & Goa, Vidarbha, coastal Andhra Pradesh, Telangana, Tamil Nadu, interior Karnataka and Kerala.

9.2. *Heavy rainfall during July*

During the month, *very heavy* rainfall occurred on 12 days in Sub-Himalayan West Bengal & Sikkim; on 4 to 7

**TABLE 16**

**Characteristics of monsoon rainfall**

| S. No | Sub – division | (No. of days) | | | |
|---|---|---|---|---|---|
| | | Vigrous | Active | Very heavy | Heavy |
| 1. | Andaman & Nicobar Islands | - | - | - | 11 |
| 2. | Arunachal Pradesh | 2 | 28 | 8 | 20 |
| 3. | Assam & Meghalaya | - | 12 | 21 | 30 |
| 4. | Naga, Mani., Mizo. & Trip. | 2 | 12 | 12 | 7 |
| 5. | S.H.W.B. & Sikkim | 5 | 23 | 26 | 34 |
| 6. | Gangetic West Bengal | 1 | 12 | 4 | 16 |
| 7. | Orissa | 4 | 19 | 15 | 27 |
| 8. | Jharkhand | - | 17 | 3 | 8 |
| 9. | Bihar | 5 | 12 | 10 | 18 |
| 10. | East Uttar Pradesh | 2 | 3 | 17 | 29 |
| 11. | West Uttar Pradesh | - | 1 | 16 | 12 |
| 12. | Uttaranchal | - | 2 | 9 | 18 |
| 13. | Haryana | 3 | 9 | 11 | 19 |
| 14. | Punjab | 5 | 2 | 2 | 5 |
| 15. | Himachal Pradesh | 5 | 9 | 7 | 13 |
| 16. | Jammu & Kashmir | - | - | 2 | 8 |
| 17. | West Rajasthan | - | - | 1 | 11 |
| 18. | East Rajasthan | - | - | 6 | 17 |
| 19. | West Madhya Pradesh | 4 | 15 | 4 | 11 |
| 20. | East Madhya Pradesh | 4 | 23 | 7 | 24 |
| 21 | Gujarat Region | 7 | 14 | 12 | 20 |
| 22. | Saurashtra & Kutch | 6 | 13 | 8 | 9 |
| 23. | Konkan & Goa | 1 | 9 | 21 | 30 |
| 24. | Madhya Maharashtra | 1 | 8 | 8 | 27 |
| 25. | Marathwada | - | 12 | 2 | 6 |
| 26. | Vidarbha | - | - | 5 | 11 |
| 27. | Chattisgarh | 5 | 17 | 5 | 16 |
| 28. | Coastal Andhra Pradesh | 3 | 22 | 3 | 11 |
| 29. | Telangana | 7 | 20 | 2 | 11 |
| 30. | Rayalaseema | 4 | 6 | - | 4 |
| 31. | Tamil Nadu & Pondicherry | - | - | 3 | 9 |
| 32. | Coastal Karnataka | 1 | 17 | 13 | 19 |
| 33. | North interior Karnataka | 2 | 2 | 3 | 5 |
| 34. | South interior Karnataka | - | 9 | 5 | 16 |
| 35. | Kerala | - | 13 | 10 | 26 |
| 36. | Lakshadweep | - | - | 2 | - |

days in Arunachal Pradesh, Assam & Meghalaya, west Uttar Pradesh, Haryana, Gujarat State, Konkan & Goa, Madhya Maharashtra and Vidarbha and on 1 to 3 days in Nagaland-Manipur-Mizoram-Tripura, Gangetic West Bengal, Orissa, Jharkhand, east Uttar Pradesh, Punjab, Himachal Pradesh, Rajasthan, Madhya Pradesh, Marathwada, Chattisgarh, coastal Andhra Pradesh, Telangana, Tamil Nadu, coastal & north interior Karnataka and Kerala. *Heavy* rain also occurred on 12 to 15 days in Assam & Meghalaya, Konkan & Goa and Kerala; on 8 to 11 days in Arunachal Pradesh, Sub-Himalayan West Bengal & Sikkim, east Uttar Pradesh, Gujarat Region, Madhya Maharashtra and south interior Karnataka; on 4 to 7 days in Andaman & Nicobar Islands, Bihar, Uttaranchal, Haryana, Himachal Pradesh, Jammu & Kashmir, east Madhya Pradesh, Saurashtra & Kutch, Marathwada, Vidarbha, Chattisgarh, coastal Andhra Pradesh and coastal Karnataka and on 1 to 3 days in Nagaland-Manipur-Mizoram-Tripura, Gangetic West Bengal, Jharkhand, west Uttar Pradesh, Punjab, Rajasthan, west Madhya Pradesh, Telangana, Rayalaseema, Tamil Nadu and north interior Karnataka.

### 9.3. *Heavy rainfall during August*

During the month, *very heavy* rainfall occurred on 4 to 5 days in Sub-Himalayan West Bengal & Sikkim, Bihar, west Uttar Pradesh, Haryana and east Rajasthan and on 1 to 3 days in Arunachal Pradesh, Assam & Meghalaya, Nagaland-Manipur-Mizoram-Tripura, Gangetic West Bengal, Orissa, Jharkhand, east Uttar Pradesh, Uttaranchal, Himachal Pradesh, Jammu & Kashmir, Saurashtra & Kutch, Konkan & Goa, Madhya Maharashtra, Vidarbha, Chattisgarh, coastal Andhra Pradesh, Telangana, Tamil Nadu, Karnataka and Kerala. *Heavy* rain has also occurred on 9 to 13 days in east Rajasthan, east Madhya Pradesh, Konkan & Goa and Kerala; on 4 to 8 days in Arunachal Pradesh, Assam & Meghalaya, West Bengal & Sikkim, Orissa, Bihar, Uttar Pradesh, Uttaranchal, Haryana, west Rajasthan, west Madhya Pradesh, Gujarat Region, Madhya Maharashtra, Chattisgarh and coastal & north interior Karnataka and on 1 to 3 days in Andaman & Nicobar Islands, Jharkhand, Punjab, Himachal Pradesh, Jammu & Kashmir, Saurashtra & Kutch, Marathwada, Vidarbha, coastal Andhra Pradesh, Telangana, Rayalaseema, Tamil Nadu and north interior Karnataka.

### 9.4. *Heavy rainfall during September*

During the month, *very heavy* rainfall occurred on 7 to 9 days in Orissa and east Uttar Pradesh; on 4 to 6 days in west Uttar Pradesh, Uttaranchal, east Madhya Pradesh and on 1 to 3 days in Arunachal Pradesh, Nagaland-Manipur-Mizoram-Tripura, Sub-Himalayan West Bengal & Sikkim, Bihar, Haryana, Punjab, Himachal Pradesh, east Rajasthan, west Madhya Pradesh, Konkan & Goa, Madhya Maharashtra, Marathwada, Chattisgarh, Tamil Nadu and north interior Karnataka. *Heavy* rain also occurred on 8 to 10 days in Assam & Meghalaya, Sub-Himalayan West Bengal & Sikkim, Orissa, east Uttar Pradesh and Uttaranchal; on 4 to 7 days in Andaman & Nicobar Islands, Jharkhand, Bihar, west Uttar Pradesh, Haryana, Himachal Pradesh, east Madhya Pradesh, Madhya Maharashtra, Chattisgarh, Telangana and Tamil Nadu and on 1 to 3 days in Arunachal Pradesh, Nagaland-Manipur-Mizoram-Tripura, Gangetic West Bengal, Punjab, Jammu & Kashmir, Rajasthan, west Madhya Pradesh, Gujarat Region, Konkan & Goa, Vidarbha, coastal Andhra Pradesh, Rayalaseema, coastal & north interior Karnataka and Kerala.

## 10. Significant temperature during the season

Significant temperatures were noticed only in the month of June. It was *appreciably to markedly above normal* or *above normal* in Haryana, Punjab, west Rajasthan and east Rajasthan during July and first half of August. Remaining period of the season, the temperatures were within reasonable limits.

*Severe heat wave* conditions prevailed on 5 to 8 days in Vidarbha, Chattisgarh and coastal Andhra Pradesh, 2 to 4 days in Orissa, Rajasthan, Madhya Pradesh and Telangana and one day each in Uttaranchal and north Interior Karnataka. *Heat wave* conditions prevailed on 9 to 12 days in Orissa, Uttaranchal, Rajasthan, Madhya Pradesh, Chattisgarh and Coastal Andhra Pradesh, on 4 to 8 days in Jharkhand, Bihar, Punjab, Telangana and Rayalaseema and on 1 to 3 days in Uttar Pradesh, Madhya Maharashtra, Marathwada, Tamil Nadu and Karnataka during June. Highest maximum temperature of 50° C was recorded at Titlagarh in Orissa on 1 June.

## 11. Disastrous weather events and damage during monsoon months

### 11.1. *June*

The death toll due to the severe heat wave conditions in May over many parts of the country continued to mount

during the first fortnight of June and it crossed 1400 altogether in Coastal Andhra Pradesh. Apart from this there were reports of deaths of 47 persons in Maharashtra, 24 in Uttar Pradesh, 6 in Assam, 5 in Madhya Pradesh and 2 in Karnataka due to heavy rain, floods, lightning, squall, duststorm, thunderstorm, landslides etc.

11.2. *July*

During the month weather related natural hazards like floods, landslides, heavy rain, lightning etc. took a toll of 164 in Himachal Pradesh, 26 in Rajasthan, 24 in Gujarat, 18 in Assam, 11 in Bihar, 8 in Uttar Pradesh, 6 in Haryana and 5 in Uttaranchal. The death toll in Himachal Pradesh occurred due to labourers being washed away in flash floods, which followed a cloudburst.

11.3. *August*

Altogether 40 people died in Himachal Pradesh, 20 in Gujarat, 12 in Uttar Pradesh, 8 in Bihar and 4 in Vidarbha due to various incidents of flash floods, lightning and incessant rains during the month.

11.4. *September*

During the month, floods claimed the lives of 179 persons in Bihar, 158 in Uttar Pradesh and 16 in Orissa.

## 12. Damage due to floods etc. during monsoon season

According to press reports and other disaster reports, weather related natural hazards took a toll of 783 people in different parts of the country. Himachal Pradesh was the most affected sub-division where 204 people lost their lives mainly due to flash floods and landslides. Other mainly affected areas are Uttar Pradesh (202) and Bihar (188). Apart from flood in river Bramhaputra, cloudbursts lightning etc. were also some of the major causes of death toll during the season.

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## Appendix

### Definitions of the terms given in '*Italics*'

### Rainfall

| | | |
|---|---|---|
| *Excess* | - | percentage departure from normal rainfall is +20% or more. |
| *Normal* | - | percentage departure from normal rainfall is between –19 % to +19 %. |
| *Deficient* | - | percentage departure from normal rainfall is between –20 % to –59 %. |
| *Scanty* | - | percentage departure from normal rainfall is between –60 % to –99 %. |
| *Widespread (Most places)* | - | 75 % or more stations of a meteorological sub-division reporting at least 2.5 mm rainfall. |
| *Fairly widespread (Many places)* | - | 51% to 74 % stations of a meteorological sub-division; reporting at least 2.5 mm rainfall. |
| *Heavy rain* | - | rainfall amount from 6.5 cm to 12.4 cm. |
| *Very heavy rainfall* | - | rainfall amount more than 12.5 cm. |

### Monsoon activity

| | | |
|---|---|---|
| *Active* | - | average rainfall of a sub-division is more than 1½ to 4 times the normal with minimum 5 cm along the west coast and 3 cm elsewhere in atleast two stations in the sub-division. |
| *Vigorous* | - | average rainfall of a sub-division is more than 4 times or more than the normal with minimum 7 cm along the west coast and 5 cm elsewhere in atleast two stations in the sub-division. |

**Maximum/day temperatures**

*Heat wave conditions* - departure of maximum temperature from normal is between +4° C to +5° C or more for the regions where the normal maximum temperature is more than 40° C and departure of maximum temperature from normal is +5° C to +6° C for regions where the normal maximum temperature is 40° C or less. (declared only when the maximum temperature of a station reaches atleast 40° C for plains and atleast 30° C for hilly region)

*Markedly above normal* - departure of maximum temperature from normal is between +5° C to +6° C for the regions where the normal maximum temperature is 40° C or less.

*Appreciably above normal* - departure of maximum temperature from normal is between +3° C to +4° C for the regions where the normal maximum temperature is 40° C or less.

*Appreciably below normal* - departure of maximum temperature from normal is between –3° C & –4° C.

*Markedly below normal* - departure of maximum temperature from normal is –5° C or less.