The Asian Summer Monsoon in 2008

By the NCEP/CPC Global Monsoons Team

1. Summary

Overall, the Asian monsoon rainfall was above normal in summer 2008. Above-normal rainfall occurred over the tropical Indian Ocean (except the tropical southeastern sector), Arabian Sea, Bay of Bengal, northern India, and the southern hill of Tibetan Plateau. Above-normal rainfall also occurred over southern China, northern South China Sea, and much of East Asia and the maritime continent. On the other hand, below-normal rainfall was observed over central-southern India, Pakistan, southern-eastern Indo-China peninsula, and northern China.

The monsoon circulation over much of southern Asia was near normal except the stronger-than-normal southwesterlies over northern Arabian Sea and northwestern India associated with the above normal Somali jet and over southern China and northern South China Sea associated with the below normal subtropical high over northwestern Pacific. The broad-scale Webster-Yang dynamical monsoon index was below normal in summer 2008.

The onset of summer monsoon was earlier than normal over the Indo-India peninsula, the South China Sea, and India. The onset of Mei-yu over East Asia was also earlier than normal.

One of the remarkable features of the Asian summer monsoon in 2008 was the heavy and persistent monsoon rainfall over northern India. In spite of an early onset, heavy monsoon rainfall quickly shifted northward and left relatively dry condition to the south. It was also interesting to note that the heavy rainfall over northern India appeared even before the summer monsoon season. Another distinctive feature observed in summer 2008 was the strong zonal dipole of precipitation over the tropical Indian Ocean, with above (below) normal precipitation over the west (east). This dipole, linked to the zonal dipole in sea surface temperature, appeared persistently during the entire summer.

2. Precipitation patterns

Figure 1 shows the anomalies of accumulated precipitation for 30 May – 28 August 2008. Above normal precipitation occurred over most of tropical-subtropical Asia and adjacent oceans, especially over the western tropical Indian Ocean, northeastern India, Bay of Bengal, southern China, South China Sea, and the maritime continent. Above normal precipitation also appeared over the northwestern Pacific, north of 10N. On the contrary, below normal precipitation was observed over central-southern India, southern Pakistan, southeastern Indo-China peninsula, tropical western Pacific (east of 140°E), and the waters to the east of Taiwan and south of Japan. A distinctive center of negative precipitation anomalies appeared over the east of tropical southern Indian Ocean (off southwestern Indonesia), forming a dipole pattern with the center of positive anomalies over the western tropical Indian Ocean. (The anomalies of precipitation over Myanmar may not be real because of problems in the data reported.) The features of this dipole structure and the positive anomalies of precipitation over northeastern India will be further discussed later.

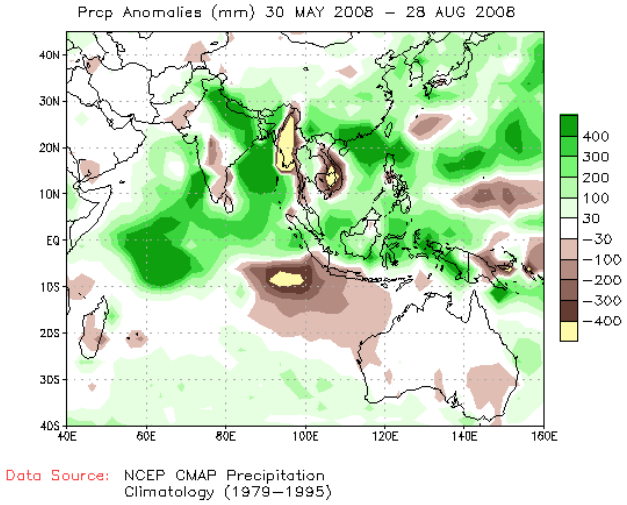


Fig. 1. Anomalies of accumulated precipitation (in mm) for 30 May – 28 August 2008. The CMAP data set is used, and the climatology period is 1979-1995. (From http://www.cpc.ncep.noaa.gov/products/Global_Monsoons/Asian_Monsoons/precip_monitoring.shtml)

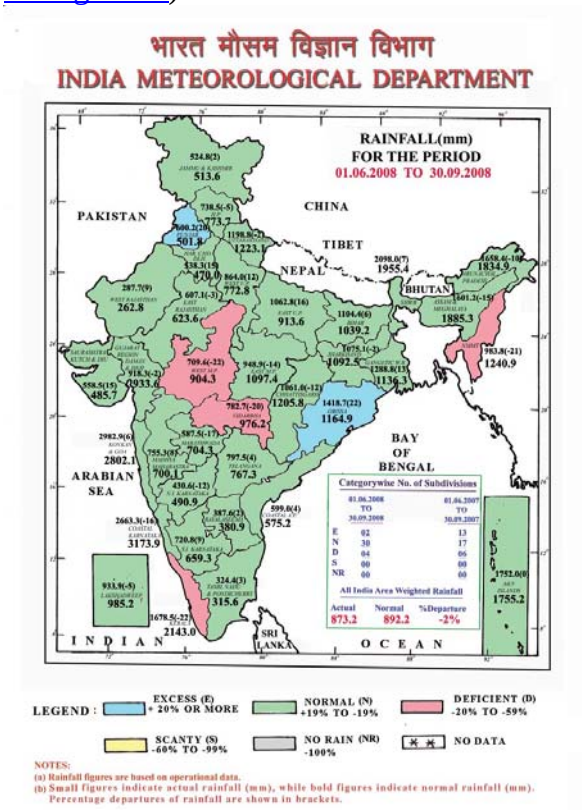


Fig. 2. Distributions of June-September rainfall (in mm) and its departure in 2008. (From the Indian Meteorological Department)

Figure 2 shows the distribution of summer rainfall over India for June-September 2008. The monsoon rainfall was above normal over small portions in northwestern and

east coast of India, but below normal over the southwest coast (Kerala), central, and eastern portions of the country. As a whole, the all-India summer monsoon rainfall in 2008 was two percent below normal.

3. Atmospheric circulation and surface temperature patterns

In summer 2008, the South Asian high and the easterly jet stream at the upper troposphere were near normal (Fig. 3, upper panel). A weak anomalous anti-cyclonic

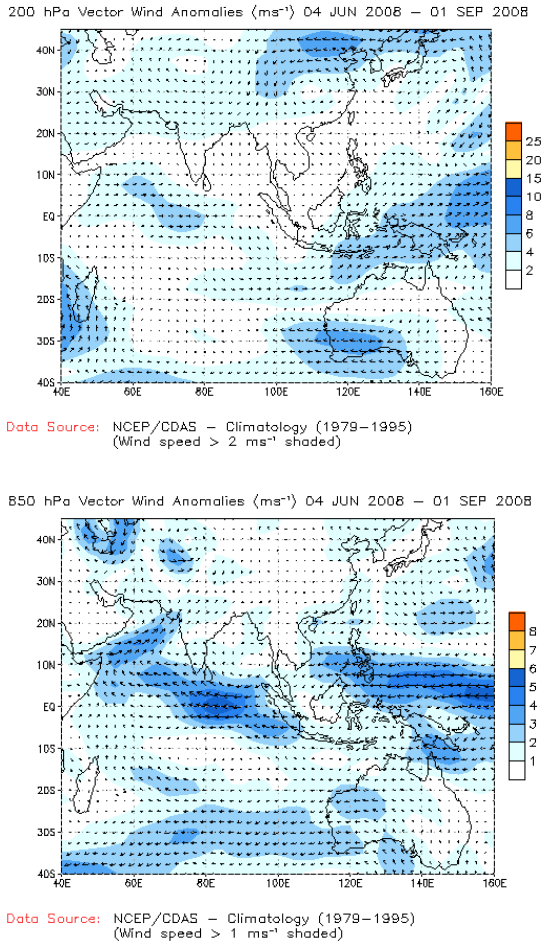


Fig. 3. Anomalies of 200-mb winds (upper panel) and anomalies of 850-mb winds (lower panel) for 4 June – 1 September 2008. Units are in ms^{-1}. (From http://www.cpc.ncep.noaa.gov/products/Global_Monsoons/Asian_Monsoons/circulation_monitoring.shtml)

pattern and a weak anomalous cyclonic pattern were located over subtropical western and eastern Asia, respectively. Although the Somali jet was slightly stronger than normal and above-normal low-level southwesterlies were observed over the Arabian Sea, which supplied water vapor to northern India, the westerly monsoon flow was weaker than normal over most of the Indian Ocean, South China Sea, and southern Asia (Fig. 3, lower panel). A weak anomalous anti-cyclonic pattern was located over central India and western Bay of Bengal. The subtropical western Pacific ridge (near 20-35°N) was also

slightly weaker than normal. However, the trade winds over tropical western Pacific were stronger than normal. Furthermore, above-normal southwesterly flow appeared over southern China, associated with the heavy local precipitation.

Figure 4 shows that, in summer 2008, it was generally warmer than normal over Asia. However, cooler-than-normal conditions appeared over northern India, consistent with the above normal precipitation over the region. The sea surface temperature (SST; lower panel) over the Indian Ocean and western Pacific was overall near normal. Negative SST anomalies appeared over western Arabian Sea, associated with the strong southwesterly flow, and positive anomalies were found near subtropical East Asia, related probably to the weak westerly flow and the anomalous northward low-level flow over the far western Pacific (see Fig. 3).

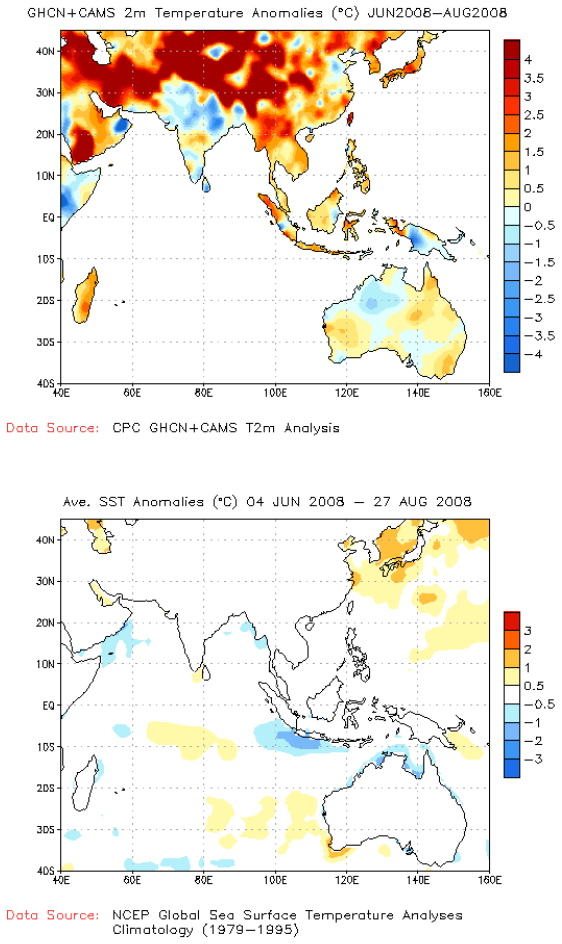
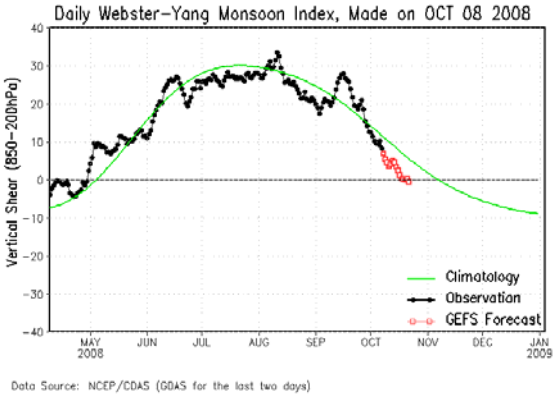
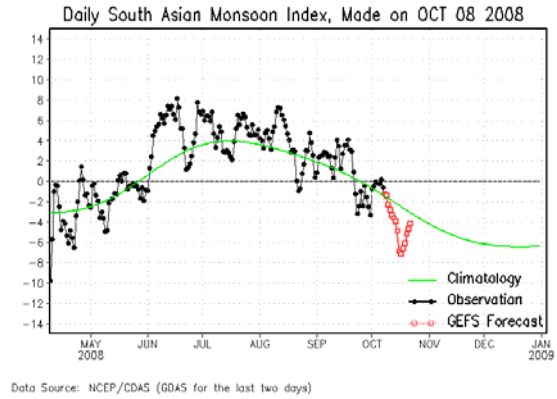


Fig. 4. Upper: Anomalies of surface air temperature (ºC) over land for JJA 2008. Lower: Anomalies of sea surface temperature (ºC) for 4 June – 27 August 2008 (from http://www.cpc.ncep.noaa.gov/products/Global_Monsoons/Asian_Monsoons/soil_olr_monitoring.shtml)

In Fig. 5, the daily values of several major dynamical monsoon indices are presented. In the figure, the green lines represent climatological values and the black lines with solid circles represent the values observed in 2008. The red lines with hollow





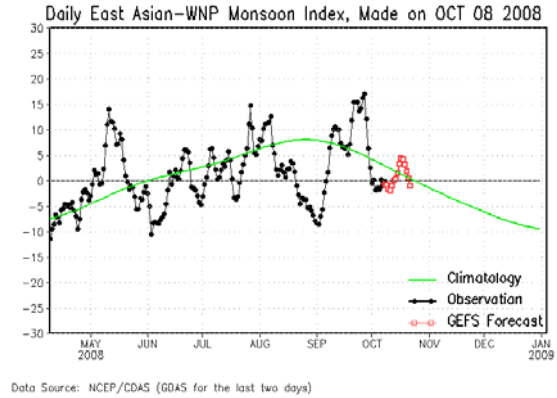


Fig. 5. Daily values of Webster-Yang monsoon index (upper panel, Webster and Yang 1992), South Asian monsoon index (middle panel, Goswami et al. 1999), and East Asia – Western North Pacific monsoon index (lower panel, Wang et al. 2008). The green lines represent climatological values and the black lines with solid circles represent the values observed in 2008. The red lines with hollow circles denote the prediction by the NCEP Global Forecast System. (From http://www.cpc.ncep.noaa.gov/ products/people/qinzhang/monsoon/index/monsoon _index.htm)

circles denote the prediction by the NCEP Global Forecast System. The upper panel shows that, in summer 2008, the Webster-Yang monsoon index (Webster and Yang 1992), which was defined as the vertical share of 850-mb and 200-mb zonal winds average over 0-20°N/40-110°E, was mostly weaker than normal except for a few days in August. The monsoon circulation over South Asia measured by the vertical share of 850-mb and 200-mb meridional winds average over 10-30°N/70-110°E (Goswami et al. 1999) fluctuated around normal in spite of a strong start in June (middle panel). This monsoon index is believed to be related to the monsoon rainfall over India, the Bay of Bengal, and part of tropical Indian Ocean. The lower panel shows that, the East Asia – Western North Pacific monsoon circulation, defined as the difference in 850-mb zonal winds between 5-15°N/90-130°E and 20-30°N/110-140°E (Wang et al. 2008), fluctuated around normal even more strongly although it was significantly weaker than normal in late August and early September.

4. Further discuss of noteworthy features

4.1 Early monsoon onsets

The Asian summer monsoon in 2008 was characterized by early starts in many places. Above normal rainfall appeared over the Indo-China peninsula in April and central South China Sea in early May. Heavy monsoon rainfall covered a large part of Bay of Bengal, South China Sea, and tropical Asian land and oceans in May with an exception over India (Fig. 6). Shown in Fig. 7 is the accumulated rainfall averaged over 15-20°N/100-105°E in the Indo-China peninsula. Despite that the local monsoon was overall below normal in the season especially from July, monsoon rainfall appeared in April with significantly above normal rainfall near the end of the month.

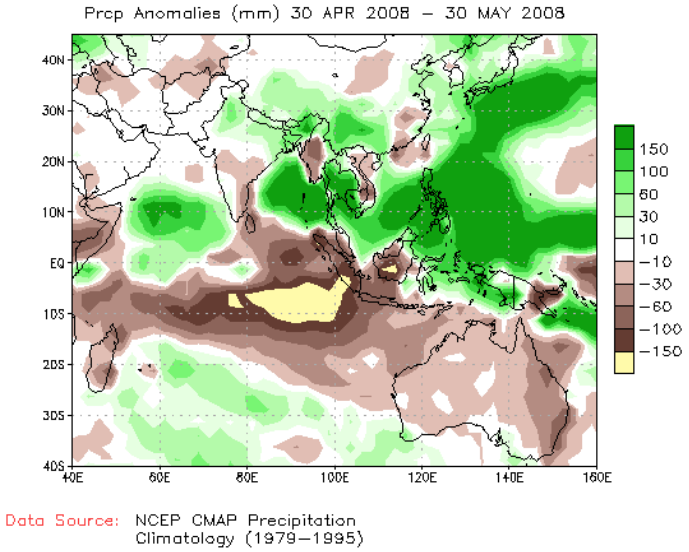


Fig. 6. Anomalies of accumulated precipitation (in mm) for 30 April - 30 May 2008. (From http://www.cpc.ncep.noaa.gov/products/Global_Monsoons/Asian_Monsoons/precip_monitoring.shtml)

One of the important features associated with the onset of Southeast Asian summer monsoon is the eastward retreat of low-level easterlies over the South China Sea and the eastward expansion of low-level westerlies over the Bay of Bengal. Figure 8 indicates that, during 23-28 April 2008, anomalous westerlies and easterlies were over the Bay of Bengal and the South China Sea, respectively. The anomalous convergence over the Indo-China peninsula increased local rainfall. Several days later, westerly monsoon flow further intensified and extended eastward to the South China Sea. Correspondingly, onset of the South China Sea monsoon took place.

The onset of the Indian summer monsoon in 2008 also occurred earlier than normal (Fig. 9). Climatologically, monsoon propagates to Kerala from the Bay of Bengal on 1 June and it takes about a month to reach northwestern India. In 2008, the monsoon appeared over southern India near the end of May and reached northwestern India around mid-June.

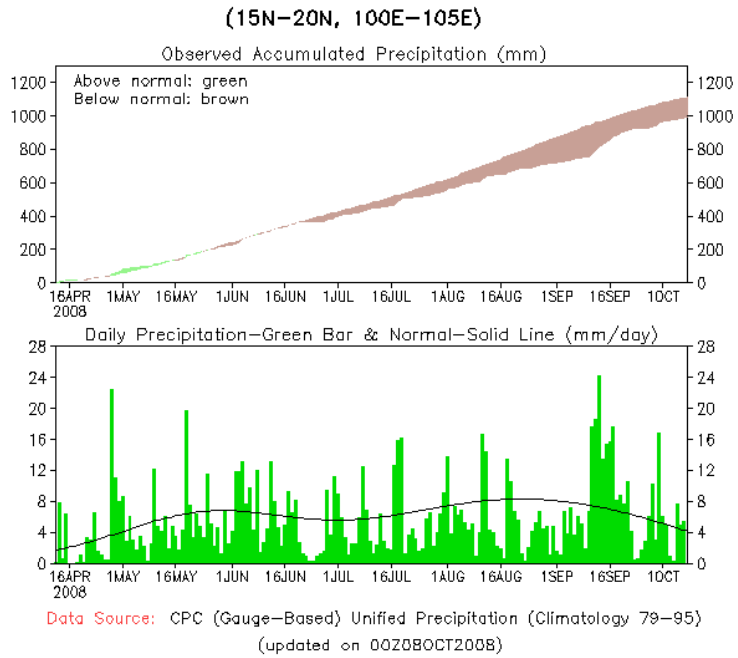


Fig. 7. Anomalies of accumulated precipitation averaged over 15-20°N/100-105°E for 180 days. The green bars measure daily precipitation and the black line depicts the climatology. (From http://www.cpc.ncep.noaa.gov/products/Global_Monsoons/Asian_Monsoons/180d-precip_click_map.shtmlhttp://www.cpc.ncep.noaa.gov/products/Global_Monsoons/Asian_Monsoons/180d-precip_click_map.shtml)

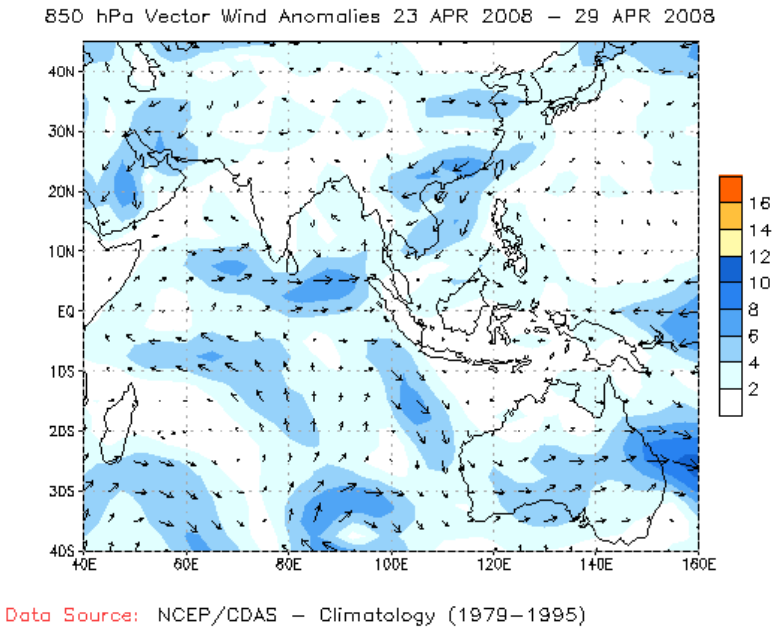


Fig. 8. Anomalies of 850-mb winds for 23-29 April 2008.

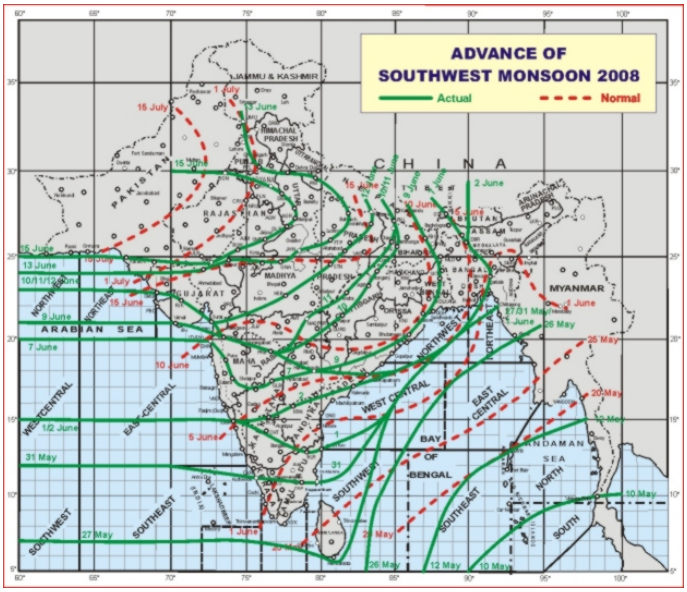


Fig. 9. Comparison of the onset dates of the Indian summer monsoon in 2008 with the climatology. (From the Indian Meteorological Department)

4.2 Precipitation over northern India

Figure 1 has shown that the monsoon rainfall over northern India was strongly above normal in summer 2008. It can be seen from Fig. 10 that the monsoon rainfall over

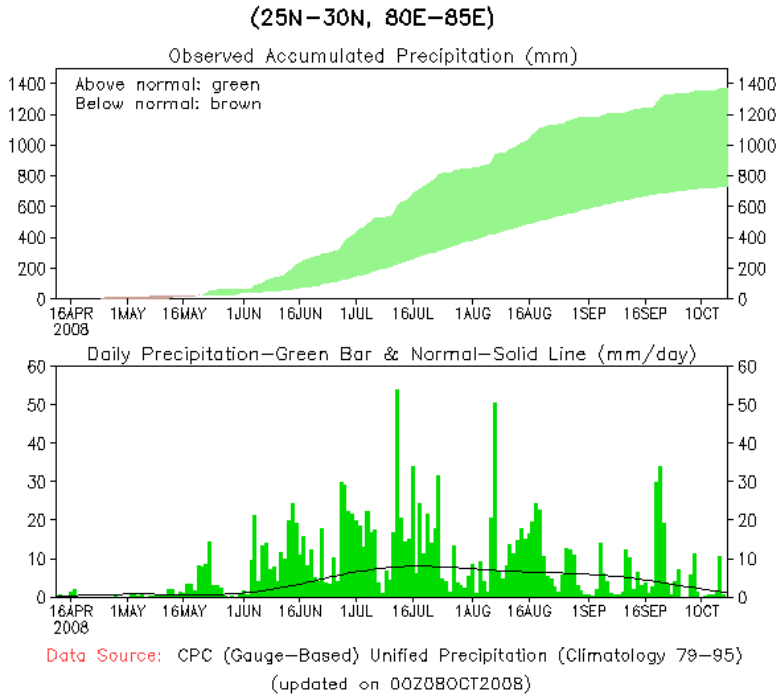


Fig. 10. Anomalies of accumulated precipitation averaged over 25-30°N/80-85°E for 180 days. The green bars measure daily precipitation and the black line depicts the climatology.

northern India and western Nepal (25-30°N/80-85°E) was persistently above normal in the season especially before late August. It should also be noted that heavy rainfall had been appeared over the region since May, before the monsoon season. This non-monsoonal rainfall may be related to mid-latitude atmospheric processes, among others.

It is also interesting to note that, over southern India, the monsoon rainfall was clearly below normal in June and most of July, in spite of the early onset of local monsoon (Fig. 11). Over southern India, major periods of good monsoon were in the late part of the season: late July – early August and the first half of September.

4.3 Mei-yu over East Asia

The onset of the Mei-yu over eastern China was also earlier than normal (about 18 June) in 2008. As shown in Fig. 12, the rainfall over 20-25°N/110-115°E was above normal from the second half of May, although the heavy rainfall may not be considered Mei-yu. The China Meteorological Administration defined an onset of Mei-yu on 7 June in Shanghai, where the period (amount) of Mei-yu was the longest (heaviest) in 26 years.

In contrast to the dry-south and wet-north monsoon pattern over India, the rainfall over northern China was below normal (Fig. 13), forming a dry-north and wet-south pattern with the above normal monsoon rainfall over southern China. That is, the north-south oriented distribution of monsoon rainfall over China was nearly opposite to that over India in summer 2008.

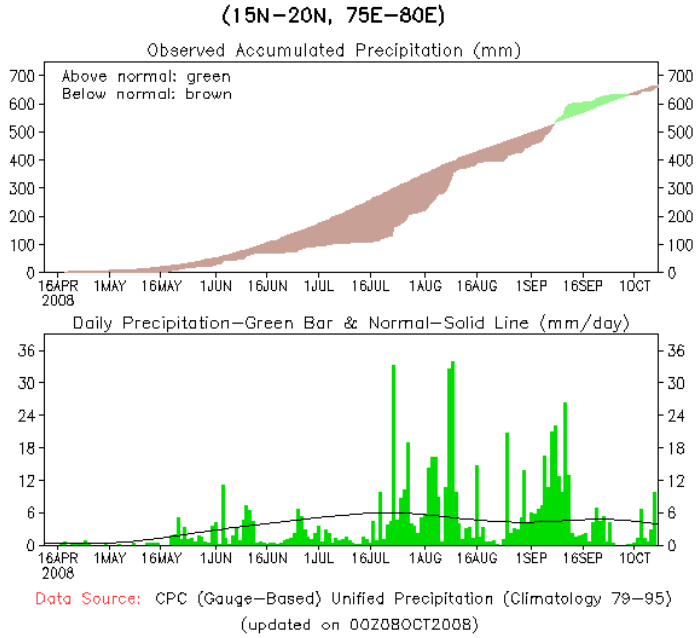


Fig. 11. Anomalies of accumulated precipitation averaged over 15-20°N/75-80°E for 180 days. The green bars measure daily precipitation and the black line depicts the climatology.

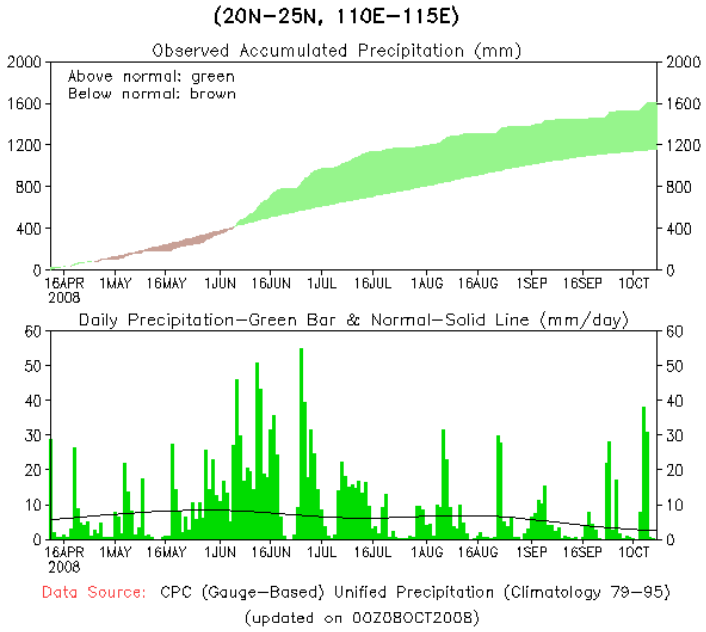


Fig. 12. Anomalies of accumulated precipitation averaged over 20-25°N/110-115°E for 180 days. The green bars measure daily precipitation and the black line depicts the climatology.

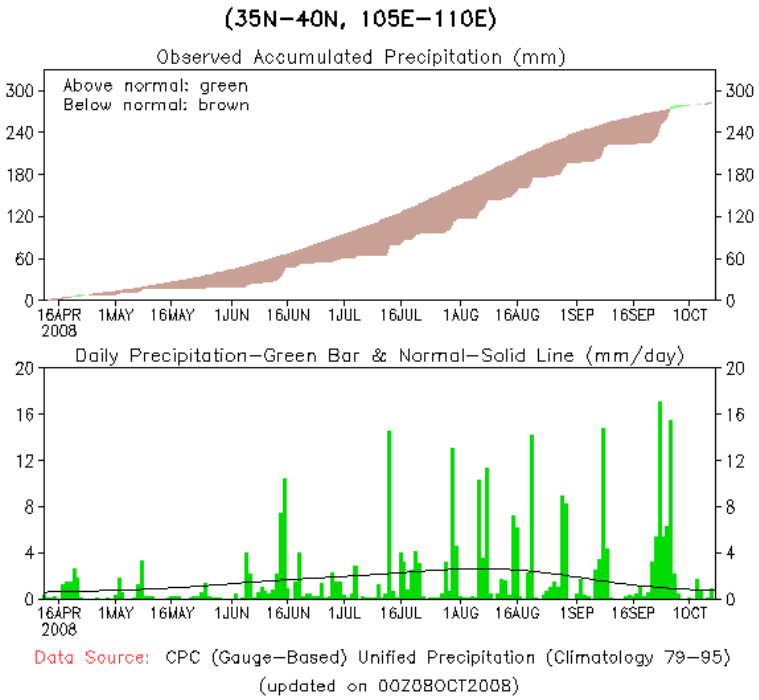


Fig. 13. Anomalies of accumulated precipitation averaged over 35-40°N/105-110°E for 180 days. The green bars measure daily precipitation and the black line depicts the climatology.

4.4 Intraseasonal variations

The 2008 Asian summer monsoon was also characterized by strong intraseasonal variability. Figure 14 indicates that, over India, most of the country especially the northern part experienced above normal or near normal monsoon rainfall during 1-18 June. However, below normal precipitation appeared over almost entire country near the end of the monsoon season in September. It can be seen from 15 that the rainfall over southeastern China (25-30°N/115-120°E) fluctuated clearly on quasi-biweekly time scale in summer 2008. Overall, the activity of tropical Madden-Julian Oscillation in summer 2008 was not significantly different from other years (see http://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/index.primjo.html).

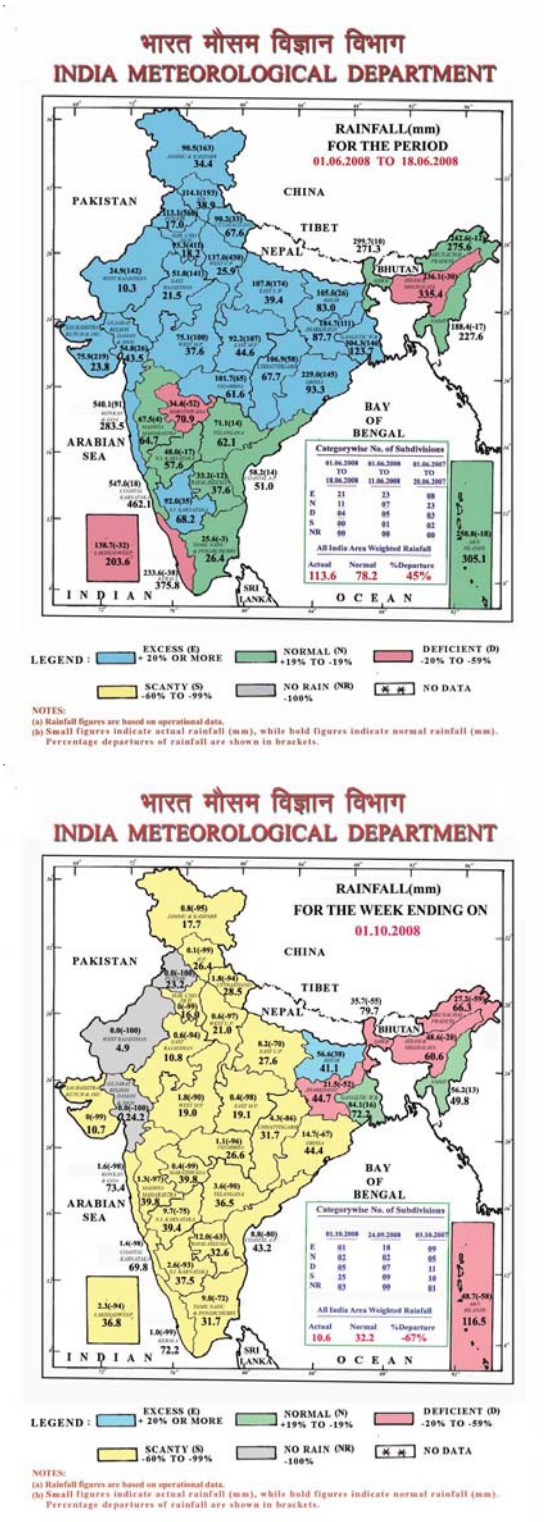


Fig. 14. Distributions of Indian monsoon rainfall (in mm) and its departure for 1-18 June 2008 (upper panel) and for 26 September – 1 October 2008 (lower panel). (From the Indian Meteorological Department)

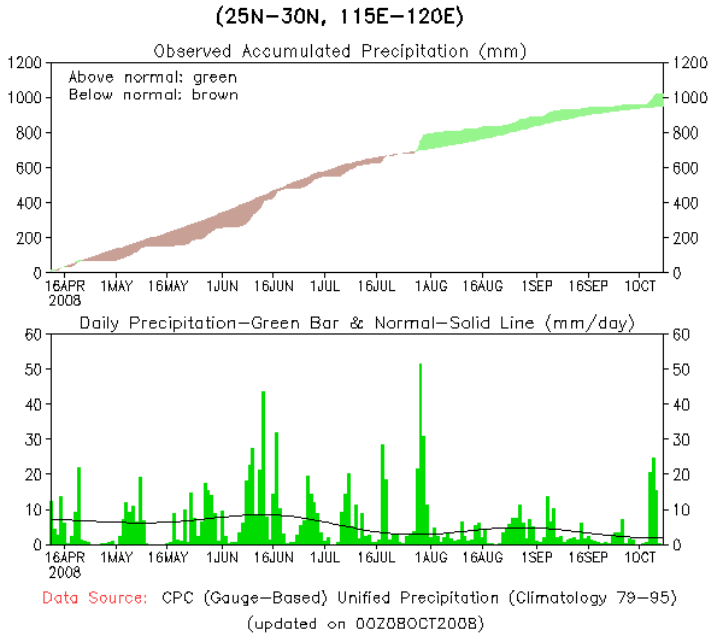


Fig. 15. Anomalies of accumulated precipitation averaged over 25-30°N/115-120°E for 180 days. The green bars measure daily precipitation and the black line depicts the climatology.

4.5 Zonal dipole over tropical Indian Ocean

A strong zonal dipole structure of precipitation was found over the tropical Indian Ocean in summer 2008, with positive anomalies over the west and negative anomalies over the east. As seen from Fig. 16, this dipole appeared clearly from early summer. It remained persistently for the entire season, linked to a strong and persistent dipole in the SST pattern (see Fig. 17).

The zonal dipole of precipitation over the tropical Indian Ocean disappeared in September (see Fig. 18). Although the positive and negative anomalies of precipitation related to the dipole pattern seemed to change their signs, the precipitation pattern in September 2008 was more clearly characterized by a zone of negative anomalies over the equatorial Indian Ocean.

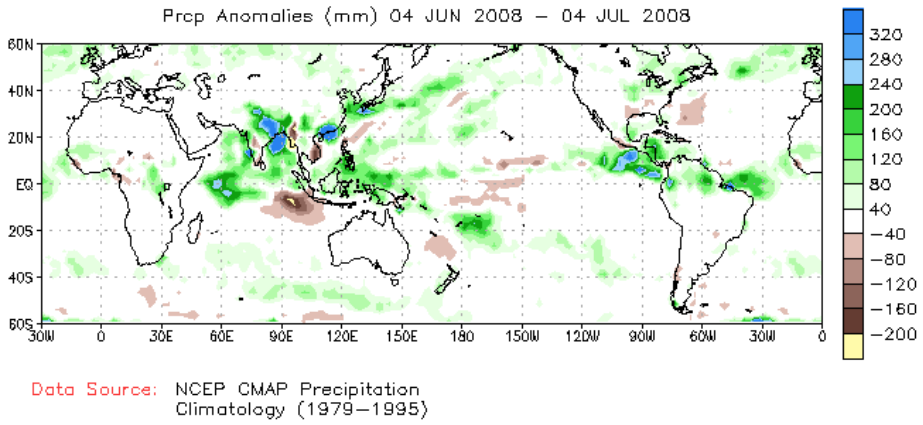


Fig. 16. Anomalies of accumulated precipitation (in mm) for 4 June – 4 July 2008. (From http://www.cpc.ncep.noaa.gov/products/Global_Monsoons/Global-Monsoon.shtml)

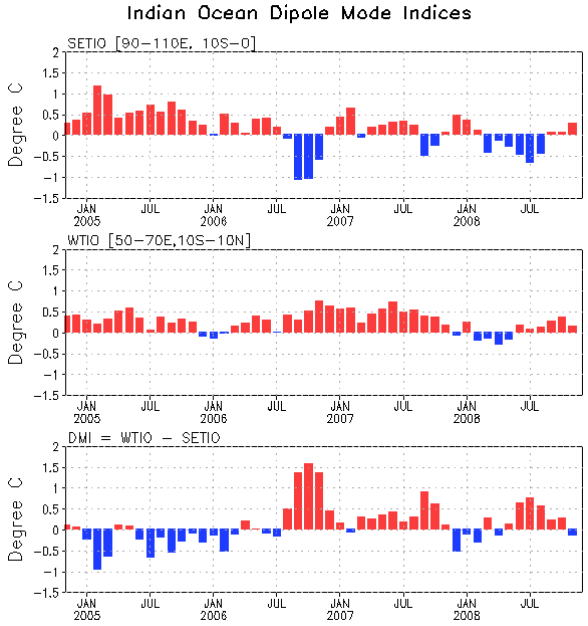


Fig. 17. Anomalies of monthly SSTs over tropical eastern (upper panel) and western (middle panel) Indian Ocean and the zonal dipole model index. (From http://www.cpc.ncep.noaa.gov/products/GODAS/ocean_briefing/mnth_sst_index_4yr.gif)

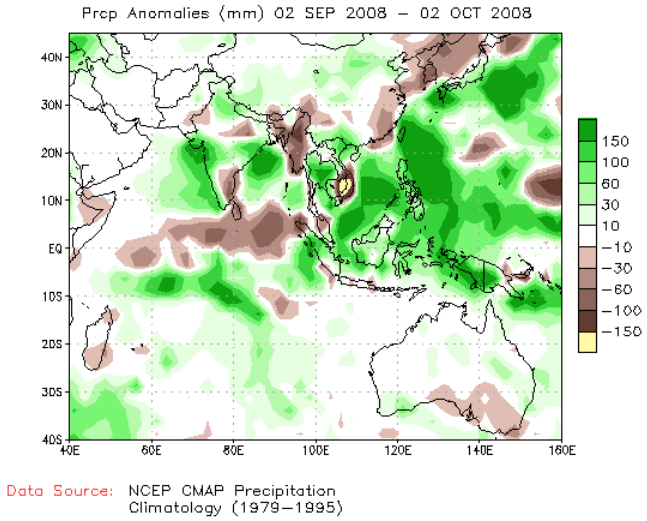


Fig. 18. Anomalies of accumulated precipitation (in mm) for 2 September – 2 October 2008.

5. References

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