

Development of Summer Monsoon and Onset of Continuous Rains over Central West Coast of India

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A new interpretation of the start of summer monsoon along central west coast of India is presented in this paper. Many authors misinterpret onset of continuous rains as start of summer monsoon front. These two are different phenomena, continuous rains happening during the last phase of monsoon development as a consequence of and after (2-5 weeks) the establishment of monsoon circulation or monsoon front. Summer monsoon front, as the term 'monsoon' originally meant, is to be delineated from the patterns of winds at surface and upto about 2 km height (observable from cloud movements) and becomes established during the first week (approximately) of May at Panjim (15°29'N and 73°49'E), a coastal station, which can be considered representative for a long coastal belt, west of Western Ghats, called here the central west coast of India. Before the establishment of summer monsoon front at Panjim, establishment of thermal front, humidity front and cloud front happen indicating start of hot and humid summer by about mid-April. Intensification of Indo-Pak Low and easterly upper tropospheric jet happen during May-June only (onset period for rain front also), two prerequisites for continuous rains. Day to day variations of surface temperatures, surface winds, humidities, clouds, upper winds and rainfalls are studied for the years 2000 and 1995 (year of earliest onset in a century and a delayed onset, respectively) to bring out patterns of change during progression of seasons. Similar situations can exist in other regions of the Asian Summer Monsoon sector with some differences.

Introduction

Indian subcontinent and adjoining areas experience an annual cycle of winds and associated weather changes resulting in two monsoons, viz, (1) summer monsoon (SM) and (2) winter monsoon (WM). This cyclic phenomenon forms part of a quasi-hemispherical system, the Asian Summer Monsoon (ASM), which encompasses many countries in east Africa, south Asia, southeast Asia and east Asia. Even though the basic features of ASM are same all over the monsoon regions, wide differences in distributions of many variables do exist from region to region. The following is a discussion bringing out the exact nature of variations of different variables at Panjim during different phases of seasons' advance, viz, dissipation or waning, transition, forming and establishment (with steadying and intensification).

Many authors write 'onset of summer monsoon', 'onset of monsoon front', 'onset of southwest monsoon front' etc., for the start of continuous rains or establishment of rain front (RF), continuous and contiguous rainfalls over large areas. Ramdas *et al*¹ called this 'the burst of the monsoon' and identified it as the date of 'actual commencement of the persistent rainfall' from a continuous plot of daily rainfalls during May and June. Deshpande *et al*² made a comparative study of onset of continuous rains in Bombay and southern Kerala, for the period

1901-1984. Chowdhury *et al*³ after studying the onsets at 15 stations in India during 1921-1986, concluded that “specification of an objective criterion for determining monsoon onset by including explicitly and implicitly parameters characteristic of monsoon is not an easy proposition”. Ramage⁴ wrote about this situation as “.....while the number of papers citing onset predictors is being overtaken by the number disproving the predictors or arguing about the definitions of onset”. This is clearly due to a mix-up between different variables of the SM, like surface wind, upper wind, surface temperature and humidity during wet spells and normal periods, caused by poor data coverage (as existed decades back) and clubbing of stations from climatically different areas.

Monsoon can be defined as reversal of a steady winter wind system resulting in another steady summer wind system^{4,5}. Wind reversals of this type are associated with changes or reversals in patterns of humidity, cloud, rain, temperature and wind at different levels. Ramage⁴ delineated four conditions for identifying a monsoon area, *viz*, (1) the prevailing wind direction shifts by at least 120° between January and July, (2) the average frequency of prevailing wind directions in January and July exceeds 40%, (3) the mean resultant winds in at least one of the months exceed 3 m/s and (4) fewer than one cyclone-anticyclone alternation occurs every two years in either month in a 5° latitude-longitude square. The first three criteria specifically deal with wind steadiness and strength only, showing the basic importance of winds in deciding the stage of development of monsoon. Hence, at a station representing a small area, development of strong and steady, reversed or nearly reversed, wind system alone is indication of establishment of monsoon circulation or monsoon front. So after dissipation of WM, leading to transition and formation of steady westerly winds, upto about 2 km height, the summer monsoon circulation or SM front can be considered to have established itself.

Materials and Methods

Data on daily temperatures (maximum and minimum), humidities, clouds, surface winds, rains and values of Indo-Pak Low (IPL) were taken from Indian Daily Weather Reports of India Meteorological Department. Directions of cloud movements for the year 2000 (April-September) were observed by the author, three times per day, at Dona Paula about a kilometre away from Panjim meteorological observatory (15°29'N and 73°49'E). Low clouds (< 2 km) and middle clouds (> 2 - < 6 km) were not separated since during SM, normally, their movements are towards east or nearly east. These visual observations are accurate only by ± 15°, especially during wet spells. Upper air winds (upto about 20 km) for 1995 and 2000 were obtained from India Meteorological Department, Pune. Years 2000 and 1995 were selected for this study^{6,7} since 2000 was abnormal with earliest onset within a century and 1995 a delayed onset year.

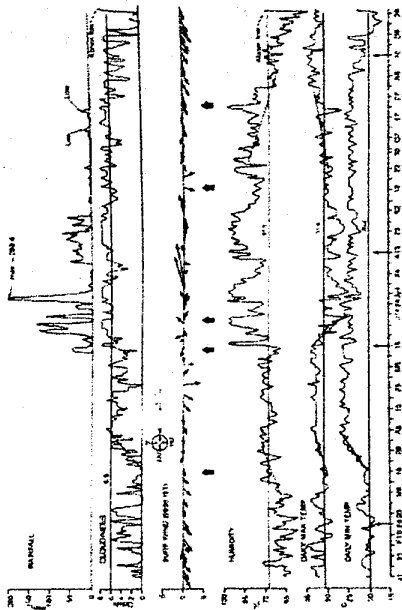


Fig. 1: Variations of surface variables at Panjim during 2000.

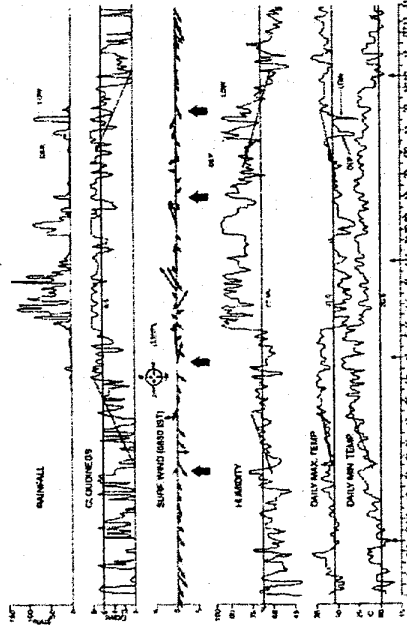


Fig. 2: Variations of surface variables at Panjim during 1995.

Results and discussion

Fig.1 shows variations of surface variables at Panjim observatory for the year 2000 (abnormal early onset of RF on 16th May). Sections between 20th February and 15th May and 13th August and 16th November are enlarged ($\times 2$) to bring out variations during transitions more clear. Both daily, maximum and minimum temperatures, showed a sharp increase from $\sim 15^{\text{th}}$ March to $\sim 5^{\text{th}}$ April.

Fig. 2 shows the variations during 1995 (delayed onset of RF on 12th June). In 1995 also, during March-April ($\sim 27^{\text{th}}$ March to $\sim 20^{\text{th}}$ April), all the variables underwent a marked increase leading to the establishment of summer season by about 20th April. Surface winds also showed unsteadying from $\sim 23^{\text{rd}}$ March and strong winds restarted only by $\sim 15^{\text{th}}$ May.

b) Cloud movements

In Fig.3 directions of movements of high clouds (>6 km) and low clouds (<2 km) or middle clouds ($>2 - <6$ km) are shown for the year 2000. Low and middle clouds are clubbed together since during SM their movements normally would be towards east or nearly east except during disturbances. Also the core of the low level westerly winds is situated around 2 km, extending more upwards than downwards.

All surface variables showed a sharp increase during the transition (winter to summer) leading to establishment of hot summer season by 5th and 20th of April in 2000 and 1995, respectively, (without establishing any surface wind patterns except unsteadiness). Early start of summer (5th April) in 2000 by ~ 10 days does

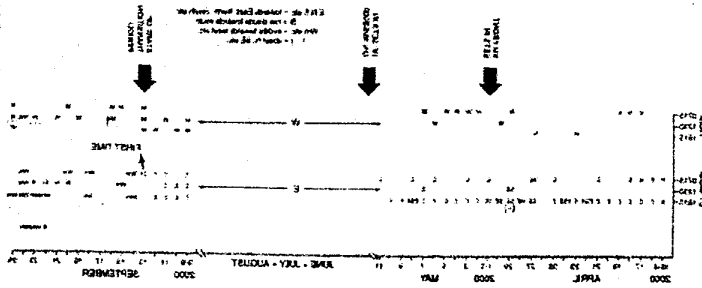


Fig. 3 Directions of cloud movements, HCM and L/MCM (high and low/middle) during premonsoon, monsoon and postmonsoon of 2000.

not seem to have primarily influenced the early start of RF (16th May) since there is a time gap of 42 days between them and since factors like IPL and EJ play major roles in the development of summer monsoon leading to start of RF. By about 15th April summer temperatures reach maximum (35-40°C) everywhere over peninsular India (south of 20°N). Increase in humidity and cloudiness in Panjim happen due to break down of steady winter (northeasterly and northerly) winds and with increase in SST and evaporation in sea with advance of summer. Regular monsoon winds at lower levels were influenced by land-sea differential heating within a narrow coastal belt whereas upper winds were influenced by a big heat trough over central and peninsular India which reaches its maximum intensity (>42°C) in May. Upper winds upto ~1.5 km (Fig. 4) showed unsteadiness during early March-April (of 2000) and by 21st April winds upto ~2 km were towards east showing the start of monsoon circulation. Even though in 1995 monsoon circulation started by 10th May (Fig.5), a normal start, onset of RF was delayed (from the mean date of 7th June) by about one week due to the break-down of IPL, before 3rd June. Cloud movements (Fig. 3) also showed high regularity of movements at L/M (low or middle) clouds' levels from 1st May onwards compared to latter half of April. Heights and base widths of cumulus clouds undergo a slow and regular change from transition to RF. First, only small patches of clouds move in from sea irregularly in evenings. Then their heights and base widths go on increasing and by ~15th April they would be much taller (~50 to ~300 m) and drizzles are possible. From 1st May onwards tall cumulus clouds (500m · 1 km) move to east and light and scattered rains are possible. Heavy rains from thunderclouds also fall infrequently. During this time more intense (x 2 or x 3) rains can happen near to the mountain ranges (about 20 km eastward). This situation of scattered and infrequent rains continue till onset of RF. These are called pre-monsoon rains in literature, but pre-RF rains seems to be the right term. Peak rainy season starts from the date of onset of RF. Ramage⁴ called the onset of RF as onset of rainy season not onset of SM.

Fig. 7 presents schematically all the fundamental points. This scheme of things is applicable all over the central west coast from about Mangalore to about

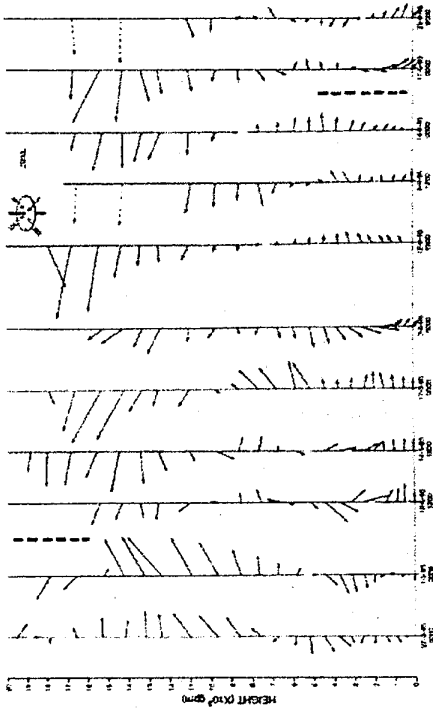


Fig.5 Vertical profiles of wind at Panjim for the year 1995.

Fig. 6 Pattern of rainfalls during the full rainy season of 2000 over two coastal meteorological subdivisions (No. 23 and 31). (See Fig. 7 for subdivisions). Data from Weekly Weather reports of India Meteorological Department. A4 is from 27th April to 3rd May (both inclusive).

● = widespread, ○ = fairly widespread, ◐ = scattered, ⊙ = isolated

Weather Station and Date (subdiv.)	Coastal Karnataka (subdiv. 31)							
	1	2	3	4	5	6	7	8
A4								
M1								
M2	●	●	●	●	●	●	●	●
M3	●	●	●	●	●	●	●	●
M4	●	●	●	●	●	●	●	●
J1	●	●	●	●	●	●	●	●
J2	●	●	●	●	●	●	●	●
J3	●	●	●	●	●	●	●	●
J4	●	●	●	●	●	●	●	●
Jy1	●	●	●	●	●	●	●	●
Jy2	●	●	●	●	●	●	●	●
Jy3	●	●	●	●	●	●	●	●
Jy4	●	●	●	●	●	●	●	●
Jy5	●	●	●	●	●	●	●	●
A1	●	●	●	●	●	●	●	●
A2	●	●	●	●	●	●	●	●
A3	●	●	●	●	●	●	●	●
A4	●	●	●	●	●	●	●	●
S1	●	●	●	●	●	●	●	●
S2	●	●	●	●	●	●	●	●
S3	●	●	●	●	●	●	●	●
S4	●	●	●	●	●	●	●	●
O1	●	●	●	●	●	●	●	●

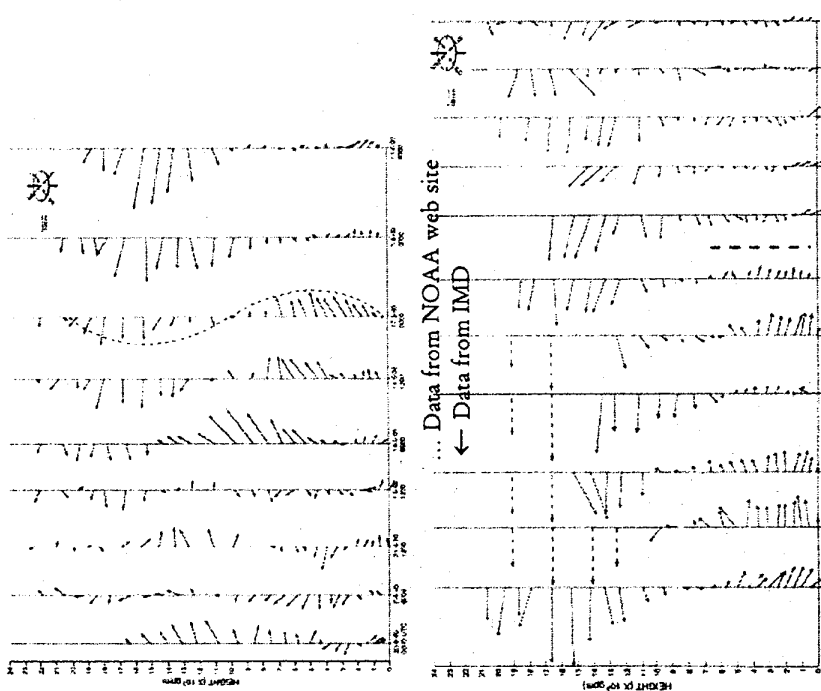


Fig. 4: Vertical profiles of winds at Panjim for the year 2000.

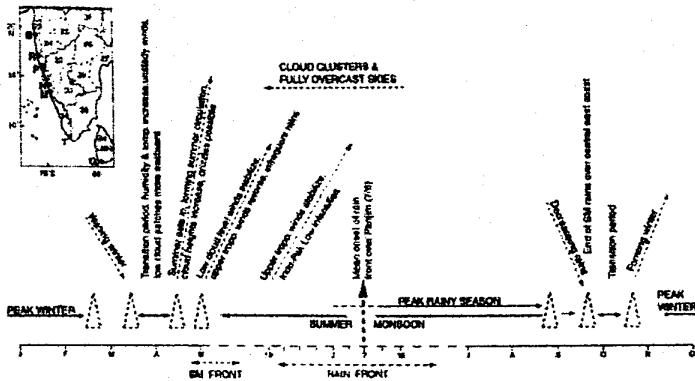


Fig. 7 Schematic picture of changes during a year highlighting the onsets of SM front and RF over central west coast. B - Bombay, R - Ratnagiri, P - Panjim, H - Honavar, M - Mangalore, T - Trivandrum and G - Galle.

Ratnagiri. Qualitatively, different phases during the development of both seasons are separated by dashed triangles. This dashed style indicates that separation time can advance or delay by about two weeks from long term mean dates. Upto SM front, development of SM is influenced heavily by local or regional drives or variables. But from SM front, intensification of IPL act as a remote drive in the formation of troughs and lows in the Arabian Sea and strengthening of Arabian Sea Low Level Jet causing onset of RF. Mean onset date for Panjim is 7th June with a standard deviation of ± 7 days⁷. Peak rainy season starts from date of onset of RF in any year (not from mean date of onset). Observed extreme dates of 16th May and 22nd June are outside $\pm 2\sigma$ limits, quite agreeing with once-in-a-century rareness. From the figure it can be easily seen that the four phases of change, viz, waning winter, transition, forming and establishment happen over a period about four months, each lasting for about one month.

Let me now identify all the physical processes (in sequence) which take place from winter transition to start of RF. (1) Summer temperature, humidity, and cloudiness are established by about 15th April (as a mean date). (2) By about first week of May SM circulation or SM front (westerly winds upto about 2 km) is established. (3) Tall (500 m – 1 km) cumulus clouds with dark bases move steadily towards east (approximately). These cause drizzles or light rains. (4) After the onset of SM front infrequent heavy rains from thunderclouds are possible. (5) Intensification of IPL and EJ starts from about mid-May and during May-June onset of RF happens with formation of an onset trough in the Arabian Sea. Deshpande *et al*² found that “on about 69% of the occasions early, normal and late onsets over southern Kerala are associated with similar onsets at Bombay”. This is mainly because, if the onset over southern Kerala is caused by a trough in the Lakshadweep Sea (as it normally happens) and if the same moves northward or

parallel to coast, the RF would set over the full west coast in phase. On 31% of the occasions the onsets were out of phase due to (1) the onsets over southern Kerala, central west coast and over Bombay were caused by different troughs or other disturbances, (2) the trough which caused onset over Kerala stopped near Mangalore or elsewhere and (3) the onset was caused by a stationary (almost) trough or disturbance. The above discussion clearly shows that SM front and RF are two different processes happening at different times during the development of monsoon.

By second half of August rainfall start decreasing and by mid-September SM rains stop over central west coast. During the transition period of September-October also infrequent rains fall due to disturbances, local or elsewhere. From about mid-October winter circulation starts forming and by ~15th November peak winter sets in over Panjim. The first cold spell comes over Panjim by late November or in December. Matsumoto⁸ presents the withdrawal in an interrelated way and finds late September as end of SM over central west coast. He also finds mid or late October as turning point for start of WM. The present results agree well with those of Matsumoto.

Conclusions

The general progression of summer and winter over the central west coast through four phases, viz., waning, transition, forming and establishment (with steadying and intensification) is well proved. These different phases during progression of seasons can advance or delay by one or two weeks. The idea that SM front starts with the onset of continuous rains (RF) is incorrect.

During 1995 and 2000 summer set in around 20th April and around 5th April respectively, leading to two widely different rainy seasons for delayed and early onsets of RF. Hence, normally, summer sets in over central west coast by about mid-April after end of transition. Summer circulation or SM front establishes by about first week of May. RF sets in between 16th May and 22nd June (say during May-June). Hence, SM front precedes RF by about one month, taking 7th June as mean date of RF onset at Panjim and summer (hot and humid) precedes SM front by about 2 weeks.

Within the extreme onset limits of RF of 16th May and 22nd June also, intensification of IPL seems to be a precondition for start of continuous rains (alternatively for start of a trough).

Peak rainy season for this region is from date of establishment of RF to about end of August. From here to mid-September, it is waning rainy season and by about mid-September monsoon circulation ends starting transition period.

Similar situations can exist in other regions of Asian Summer Monsoon, especially along western coasts with some variations. Consider the southern coastal city of Trivandrum (8°28'N and 76°57'E) early infrequent rains from April-May are common (Rao,1976). Further southwards, in Srilanka at Galle (6°2'N and

80°13'E) summer rains start much earlier in April⁹. Northwards, at Bombay (19°7'N and 72°51'E) infrequent rains come late¹⁰ in late May compared to even Panjim. In these stations also, similar to Panjim, the SM seem to establish weeks earlier to the onsets of RF.

Acknowledgements

I thank Dr. E. Desa, former Director, National Institute of Oceanography for encouragement. Cooperation from the India Meteorological Department, Pune in providing upper air radiosonde data for 1995 and 2000 is duly acknowledged. I thank Mr. S.R. Bajpai, former Director, Meteorological Observatory, Panjim, for discussions and providing some surface data.

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