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STUDY OF UNUSUAL HAILSTORM OVER BOMBAY

1. In the evening of 24 April 1988 the Calcutta bound Indian Airlines aircraft (VT-EHD) reported hailstorm over Bombay after take-off. The aircraft suffered mild damage. The hailstorm continued for about 15 minutes accompanied by squally winds and lightning followed by rain for about one and half hour. However, the whole weather phenomenon was so localised in nature that none of the observatories located at Colaba, Santacruz, Alibag, Kalyan and Thane reported any rainfall.

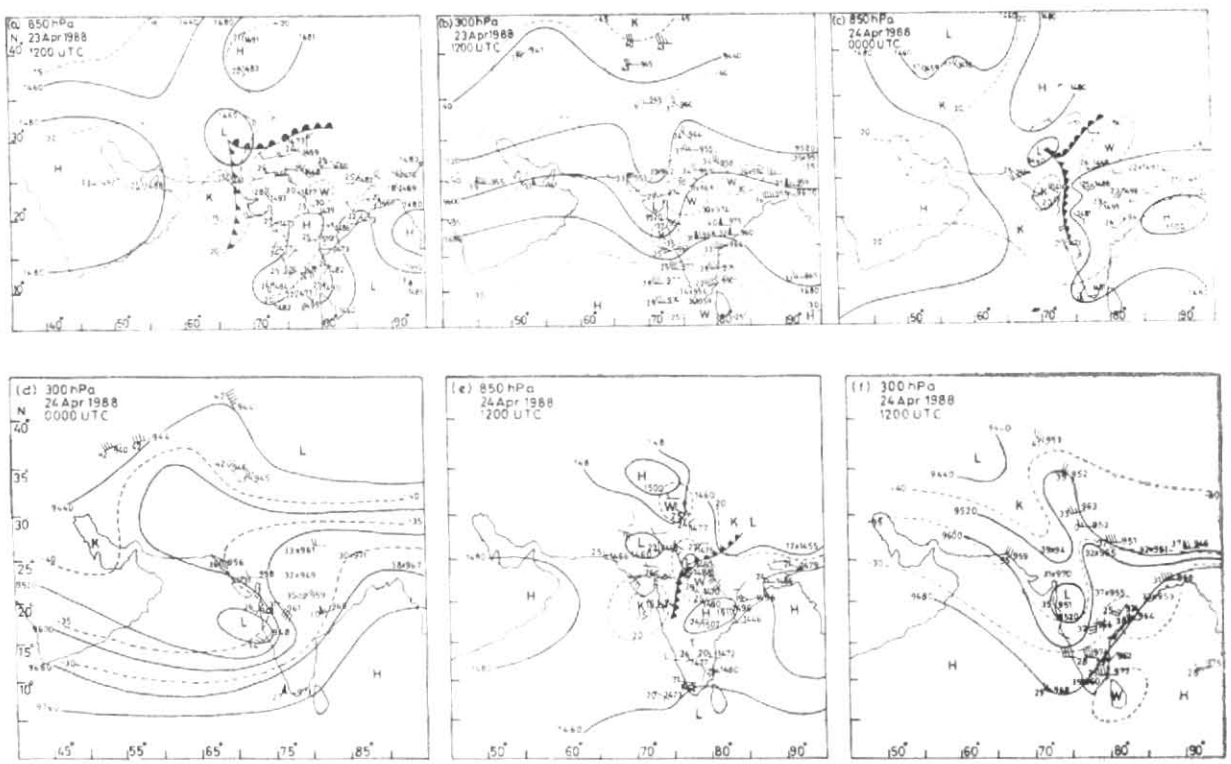
Past data indicate that the number of hailstorm days over Bombay (both Colaba and Santacruz) during the whole year is zero. Thus being a rare historical event encourages study of the phenomenon in detail and documentation.

2. Recently Misra and Prasad (1980) found that the hailstorm probability per thunderstorm in an area bounded by 15°-20°N and 70°-75°E during the month of April is only 3%. The climatological average number of days with thunder over Santacruz and Colaba during the month of April are 0.6 and 0.4 respectively. Thus, at Santacruz there could be three thunderstorm days in five years and at Colaba two thunderstorm days in five years during the month of April. Combining this with the hailstorm probability per thunderstorm one may infer statistically there may be one hailstorm day in 55 years over Santacruz and in 85 years over Colaba.

The index of the instability for thunderstorm forecasting was first given by Showalter (1953) and later similar indices were developed by many scientists (Galway 1956, Miller 1972). These are used in hail forecasting on the assumption that greater the instability index greater is the likelihood and intensity of thunderstorm with greater probability of hail formation with larger size and its reaching the ground.

3. *Synoptic situation* — In the evening of 22 April 1988 (1200 UTC) a feeble upper air trough at 300 hPa lay roughly along longitude 60° E north of latitude 35° N. Next day evening (1200 UTC) it lay as north-south trough roughly along longitude 71°E north of latitude 16°N with an embedded cyclonic circulation over east central/northeast Arabian Sea off north Maharashtra-south Gujarat coast. The thermal trough at this level was to the rear of the contour trough. Simultaneously with this a western disturbance lay over extreme west Pakistan and adjoining Afghanistan as an upper air circulation at 1.5 km asl. Evolution of the system during 1200 UTC of 23 April and 1200 UTC of 24 April is shown in Figs. 1 (a-f). Cold air advection in the lower troposphere coupled with deep trough in the upper troposphere with embedded cyclonic circultion over east central Arabian Sea off Maharashtra coast was a significant feature at 0000 UTC on 24 April. The system rapidly moved away eastwards across Madhya Maharashtra and adjoining Konkan by evening (1200 UTC) of same day.

The analysis of tephigrams of Bombay (Santacruz) clearly show that : (*i*) A downward tendency in the freezing level from 1200 UTC of 22nd to 0000 UTC of 24th



Figs. 1 (a-f). Contour and isotherm analysis of : (a) 850 hPa of 231200 UTC, (b) 300 hPa of 231200 UTC, (c) 850 hPa of 240000 UTC, (d) 300 hPa of 240300 UTC, (e) 850 hPa of 241200 UTC, and (f) 300 hPa of 241200 UTC

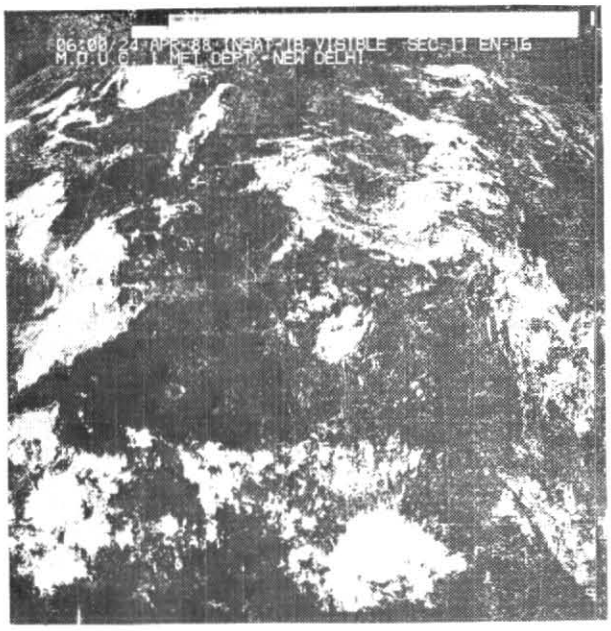


Fig. 2(a). INSAT-1B picture of 0600 UTC VIS

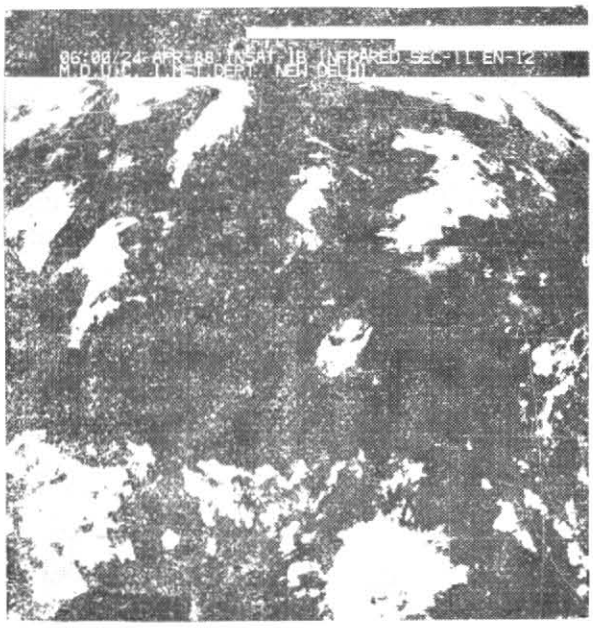


Fig. 2(b). INSAT-1B picture of 0600 UTC IR

when it reached lowest level of 615 hPa. (*ii*) There was a significant lowering in convective condensation level from 840 hPa at 0000 UTC of 24th to 950 hPa at 1200 UTC of 24th. (*iii*) A super-adiabatic lapse rate prevailed from surface to 920 hPa. This supports an auto-convection which prevailed during 1200 UTC of 24th, nearest to the time when hailstorm occurred. (*iv*) The average mixing ratio between 850 hPa and 700 hPa has increased considerably from 0000 UTC of 23rd and maintained between 6.0 and 7.0 gm/cm^3. (*v*) The Showalter stability index shows a high negative value from 1200 UTC of 23rd to 0000 UTC of 24th indicating significant instability of the atmosphere for development of convective clouds. (*vi*) The total-total index $[(T_{850} - T_{500}) + (T_{d850} - T_{500})]$ of more than 50°C is considered to be favourable for convective development and it actually happened during 1200 UTC of 23rd and 0000 UTC of 24th.

The analysis of INSAT-1B cloud pictures [Figs. 2 (a-f)] indicate some scattered clouds over north Madhya Maharashtra as seen in the visible imagery of 0600 UTC picture of 24 April which was absent in IR picture of the same time indicating that there was no vertical extension of the clouds at that time. Both visible and IR pictures of 0900 UTC indicated very bright convective clouds of almost uniform texture extending north-southwards across Madhya Maharashtra. Successive cloud pictures showed a rapid development of intense north-south oriented thunderclouds across Konkan and Madhya Maharashtra in the afternoon of 24 April 1988. The vertical extension of convective clouds was an important factor for causing hailstorm over northeastern parts of Bombay. It may be inferred from the rapid development of the convective clouds that the strong afternoon insolation might have worked as a triggering mechanism for causing the hailstorm.

4. *Observational data* — Although neither hailstorm nor rainfall was reported by either Colaba or Santacruz observatories, the sharp changes were noticed in a few surface parameters over Santacruz on 24th evening: (a) the anemograph showed backing of prevailing northwesterly wind to east to northeasterlies with a gust of about 35 kmph around 1320 UTC, (b) the thermograph showed sharp fall in temperature by about 1°C at 1320 UTC with further gradual fall by another 1.5° C between 1320 UTC and 1450 UTC, and (c) the hygrograph showed a sharp fall in relative humidity by about 25% from 60% at 1245 UTC subsequently there was a rise by about 12% till 1330 UTC. The above three observations give an evidence of presence of a downdraft from a convective cloud and suggests occurrence of a distant thunderstorm might have been accompanied with hailstorm. It may be mentioned here that there was no significant change in the self recording charts of Colaba.

5. *Conclusions* — Although a hailstorm over Bombay is a rare phenomenon in the month of April, it did occur under the influence of a rare combination of the following situation :

(*i*) Cold air advection associated with the passage of a westerly trough in the middle/upper tropospheric levels across the area.

TABLE 1

Thermodynamical parameters during 22-25 April 1988

S. No.	Parameter	Date and time							
		22		23		24		25	
		00 (UTC)	12 (UTC)	00 (UTC)	12 (UTC)	00 (UTC)	12 (UTC)	00 (UTC)	12 (UTC)
1	Freezing level	622	590	610	610	615	610	580	580
2	CCL	870	870	860	830	840	950	770	790
3	Tc/T_{1000}	35/20	32/30	35/26	36/30	35/26	27/31	36/25	37/27
4	Mixing ratio 850-700 hPa	3.90	3.00	8.0	6.25	7.0	6.0	8.0	7.0
5	Showalter stability index	3	2	0	−4	−4	1	1	−1
6	Total-total index	43	41	47	55	54	46	48	43

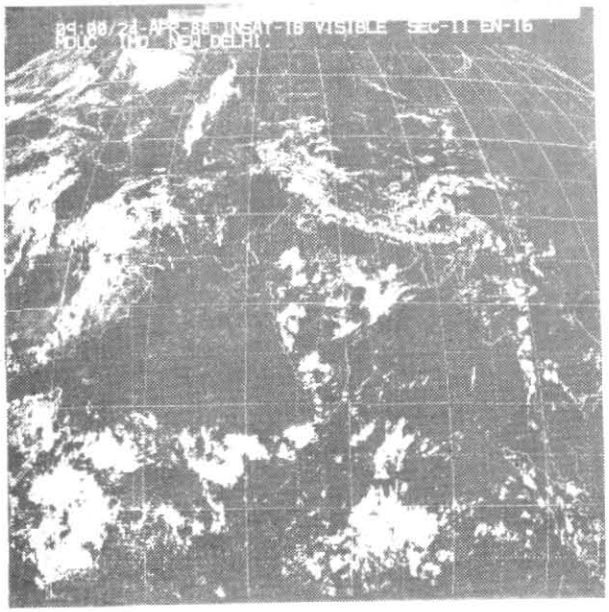


Fig. 2(c). INSAT-1B picture of 0900 UTC VIS

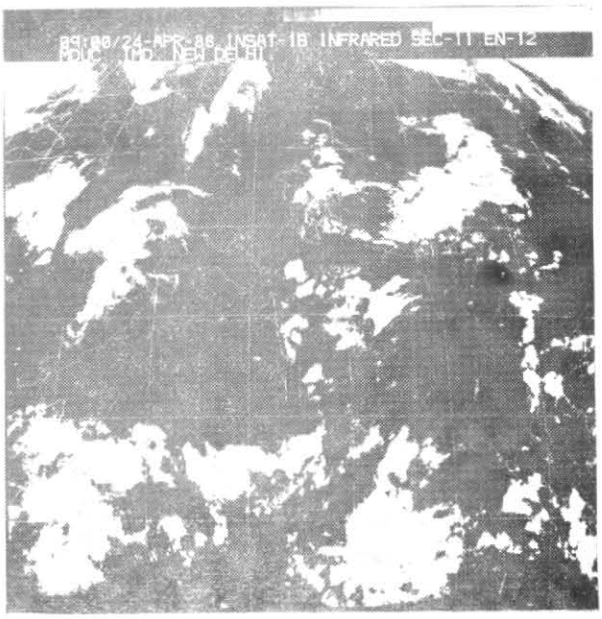


Fig. 2(d). INSAT-1B picture of 0900 UTC IR

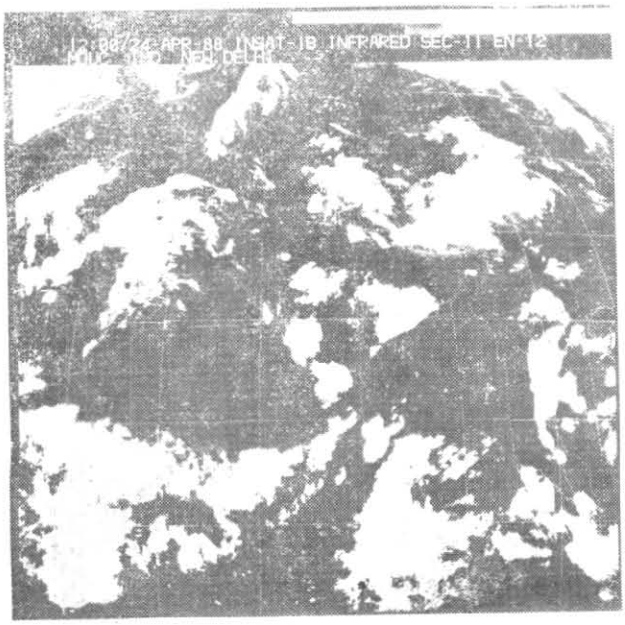


Fig. 2(e). INSAT-1B picture of 1200 UTC IR

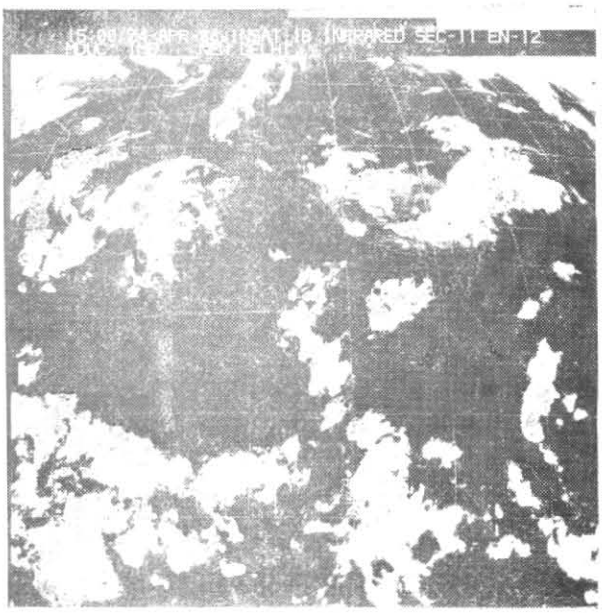


Fig. 2(f). INSAT-1B picture of 1500 UTC IR

(*ii*) Presence of super-adiabatic lapse rate near the surface (of about 70 hPa thickness) causing auto-convection.

(*iii*) Significant lowering of the convective condensation level.

(*iv*) A high negative value of Showalter stability index.

(*v*) A high value of total-total index.

(*vi*) High moisture content in the lower levels.

(*vii*) Insolation as the initial trigger for assisting intense convection.

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