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Progression of mid-tropospheric stable layer over Delhi region during May 1989 — A case study

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सार — इस शोधपत्र में दिल्ली और आस-पास के क्षेत्रों में 20 से 28 मई 1989 तक 500 और 300 एच. पी. ए. के मध्य उपरितन वायु उत्क्रमणों के गठन और क्षय के विवरणों को प्रस्तुत किया गया है और सम्बद्ध सिनॉप्टिक लक्षणों पर विचार विमर्श किया गया।

ABSTRACT. The paper presents details of the formation and dissipation of upper air inversions between 500 and 300 hPa from 20 to 28 May 1989 over Delhi and adjoining areas and discusses the associated synoptic features.

Key words — Inversion, Anti-cyclone, Trough in westerlies, Sub-tropical jet stream.

1. Introduction

The radiative temperature inversion near ground level, subsidence inversion at boundary layer heights and formation stable layer at mid-troposphere around 300 hPa during October and November months are the commonly observed phenomenon (Ananthakrishnan & Rangarajan 1963, Sen and Das 1986). Temperature inversions in the mid-troposphere do not generally occur during the month of May. However, such inversions/stable layers were noticed prominently in time and space during May 1989, over Delhi and adjoining areas. In the present paper, besides the formation and dissipation of these inversions, their association with the prevailing weather has been discussed.

2. Data used

The following data for the period 18 to 31 May 1989 were utilised in the present study:

(*i*) RS/RW ascents (both 00 UTC and 12 UTC) taken at New Delhi, Patiala, Jodhpur and Lucknow.

(*ii*) Daily weather report of Delhi, Chandigarh, Punjab, Haryana, Himachal Pradesh, Jammu & Kashmir, Rajasthan and Uttar Pradesh.

(*iii*) Upper level charts of 00 UTC and 12 UTC.

3. Observed features and discussions

The present study relates to the mid-tropospheric stable layer/inversion during the period 20 to 28 May 1989 over Delhi, Patiala, Jodhpur and Lucknow. The sequence of changes in lapse rates in layers of 50 hPa thickness from 600 hPa to 300 hPa, for the same period, over respective stations are given in Table 1. The lapse rates ($\leq$ 2.0°C/km) indicating stable layers have been shown *underlined* in the table. Tephigrams of 22 May 1989 (00 UTC) showing simultaneous occurrence of inversions at all the four stations (New Delhi, Patiala, Jodhpur and Lucknow) are shown in Fig. 1. The stable/inversion layer has prominently occurred on maximum number of occasions over Delhi as compared to Patiala, Jodhpur and Lucknow. Hence the mid-tropospheric inversion over Delhi has been studied in detail.

As may be seen from Fig. 2, a stable layer/temperature inversion between 415 hPa and 350 hPa was formed over Delhi on 20 May 1989 at 00 UTC. The base of the inversion came down to 515 hPa at 00 UTC on 21 May 1989 and remained almost at 500 hPa level with very little oscillation till 00 UTC of 24 May 1989. At 12 UTC on 24 May 1989, the base lifted to 450 hPa and later the inversion got broken and vanished. The inversion reappeared at 12 UTC on 25 May 1989, disappearing on 27 May 1989 (12 UTC) reappearing again on 27 May 1989 (12 UTC) and finally got broken and disappeared on 28 May 1989 before 12 UTC. The base of the inversion also lifted to 375 hPa level before its dissipation. The formation and dissipation of the thermal inversion and other related aspects are discussed below.

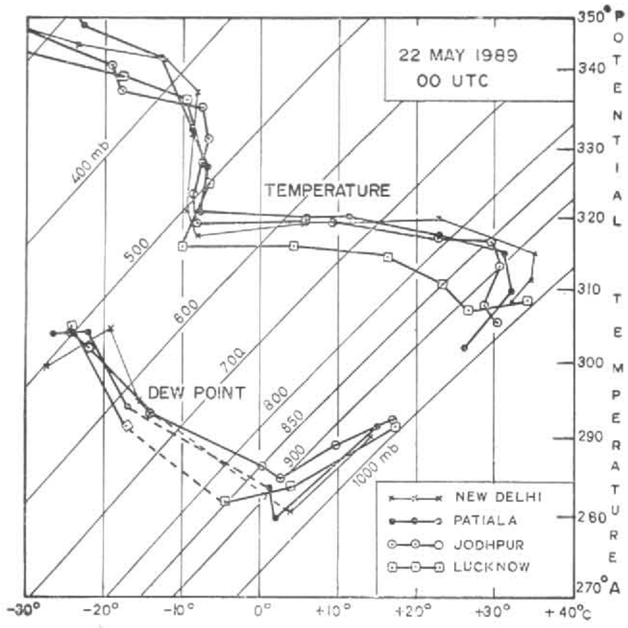


Fig. 1. Tephigram of 22 May 1989 (00 UTC) showing mid-tropospheric temperature inversion over New Delhi, Patiala, Jodhpur and Lucknow

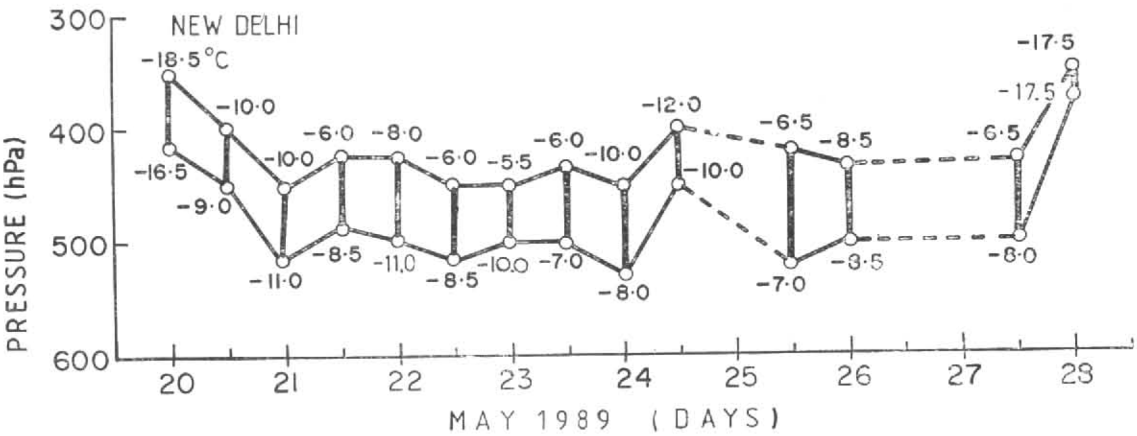
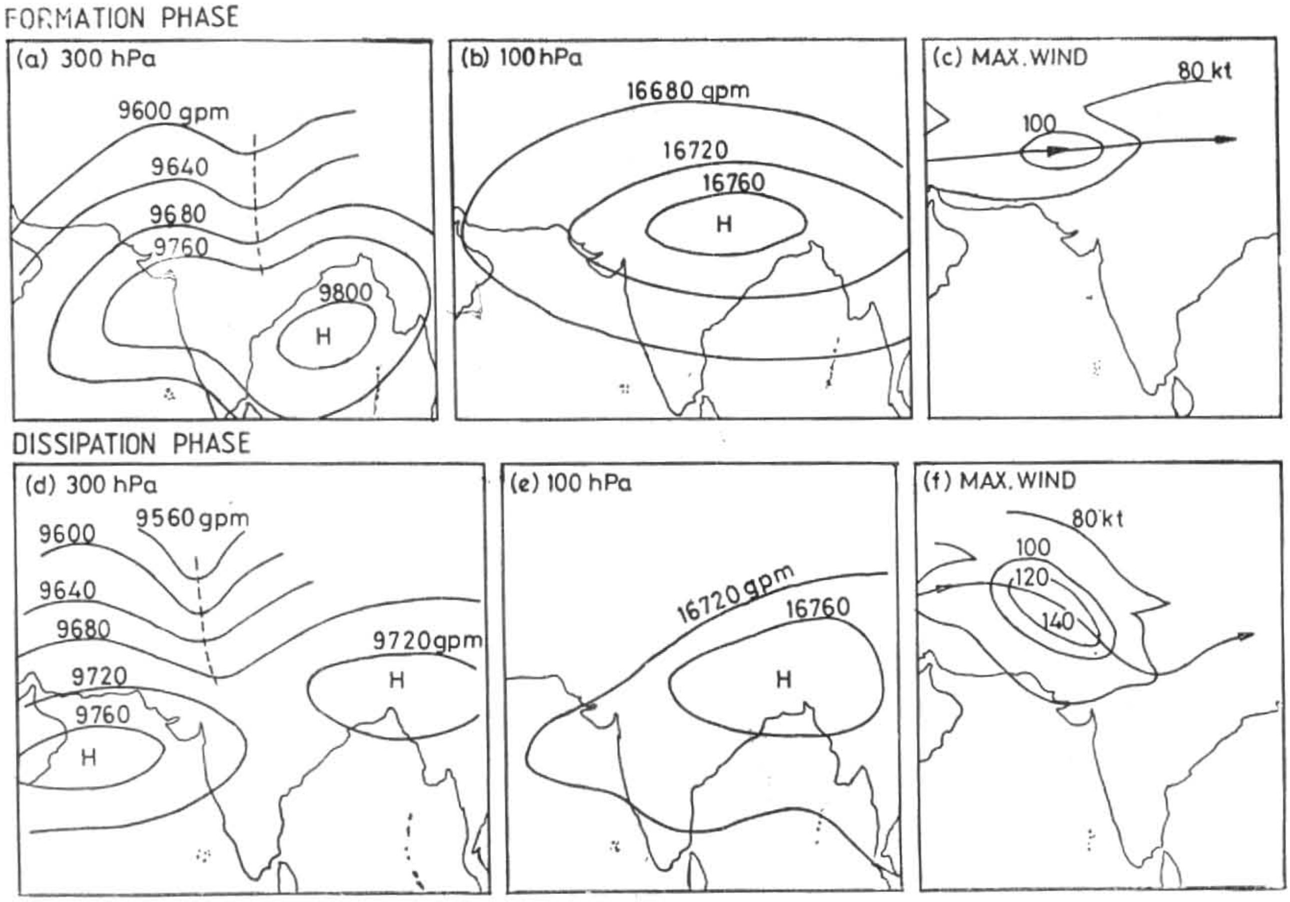


Fig. 2. Height, depth and thickness of mid-tropospheric stable/inversion layer over New Delhi



Figs. 3 (a-f). Upper air charts of NHAC during formation & dissipation phases showing : (a) Anticyclone and trough in westerlies at 300 hPa on 19 May 1989 (12 UTC), (b) Anticyclone at 100 hPa on 19 May 1989 (12 UTC), (c) Maximum wind chart on 20 May 1989 (00 UTC), (d) Anticyclone and trough in westerlies at 300 hPa on 24 May 1989 (00 UTC), (e) Anticyclone at 100 hPa on 24 May 1989 (00 UTC), and (f) Maximum wind chart on 24 May 1989 (00 UTC)

3.1. *Formation of temperature inversion*

The upper air charts reveal the persistence and movement of anti-cyclone at 300 hPa level and aloft over Delhi and adjoining areas during the period 18 to 23 May 1989. A trough in westerlies at 300 hPa was positioned along 81° E at 12 UTC on 19 May 1989, and Delhi and neighbourhood were located under the rear region of this trough. Fig. 3(a) shows, position of anti-cyclone and the trough in westerlies at 300 hPa and Fig. 3(b), the position of anti-cyclone at 100 hPa, on 19 May 1989 at 12 UTC. In addition to this, on 20 May 1989 at 00 UTC, Delhi and adjoining areas were lying under and close to the right exit regions of sub-tropical, westerly jet stream positioned along 30° N as shown in Fig. 3(c). The strong subsidence generated by these synoptic features, was responsible for the formation of the inversion below 300 hPa level.

Variation of stations level pressure, suggesting the movement of anti-cyclones is shown in Fig.4. The study of Fig. 4 in relation to Fig. 2 also reveals that though the presence of anti-cyclone aloft plays important role in formation of stable layer due to subsidence, other features such as positioning of jet stream, westerly trough etc are generally important in generating mid-tropospheric stable layer/inversion. As explained earlier, the formation has taken place on 20 May 1989, when in addition to anti-cyclones aloft, other upper air synoptic features were favourable on 19 and 20 May 1989. Similarly the upper air stable layer even though less pronounced has formed on 25 May 1989, when besides anti-cyclones aloft, the trough in westerlies at 300 hPa and the sub-tropical jet stream at 200 hPa were favourably positioned.

TABLE 1

Sequence of changes in lapse rates in the layers of 50 hPa thickness from 600 to 300 hPa on 20-28 May 1989 at 00 and 12 UTC

Thickness of layer (in hPa)	Lapse rate (°C/km)																	
	20 May		21 May		22 May		23 May		24 May		25 May		26 May		27 May		28 May	
	00	12	00	12	00	12	00	12	00	12	00	12	00	12	00	12	00	12
(a) New Delhi																		
350-300	6.7	5.7	5.6	6.2	8.1	7.4	7.0	7.3	7.9	8.7	7.7	7.8	5.1	8.8	6.3	6.2	5.3	5.3
400-350	*0.9*	5.3	7.9	6.1	7.9	6.9	7.3	7.1	5.5	4.0	3.7	6.6	6.3	5.4	6.2	6.7	3.6	4.5
450-400	6.0	*0.9*	3.8	2.3	*0.1*	5.6	5.2	2.7	4.5	*2.0*	3.1	*0.1*	*0.7*	4.2	4.1	4.4	4.2	6.4
500-450	8.4	6.3	*—1.4*	*0.4*	*0.0*	*—1.8*	*—5.5*	*—0.7*	*1.6*	5.8	4.7	2.6	3.5	5.8	5.6	*—2.5*	6.4	7.5
550-500	7.6	8.3	9.5	7.9	6.4	3.5	9.5	8.9	3.3	4.3	6.0	4.5	6.7	3.9	6.2	7.4	5.4	6.7
600-550	7.8	7.2	9.7	9.1	10.5	10.6	8.5	10.9	8.7	5.3	9.1	7.3	6.3	6.4	5.3	9.8	3.5	*2.0*
(b) Patiala																		
350-300	7.0	5.3	6.2	6.4	6.2	6.8	5.1	4.2	3.6	5.3	5.6	7.2	4.6	4.5	—	*0.1*	2.5	1.9
400-350	*0.1*	*2.0*	3.9	3.4	5.2	5.4	6.2	2.5	3.7	*2.0*	*1.0*	*0.6*	2.8	4.5	—	3.8	3.2	4.4
450-400	6.1	4.8	*1.2*	*0.2*	3.1	*1.7*	*1.7*	3.4	4.1	8.9	5.4	3.0	5.0	5.5	—	5.0	6.1	7.4
500-450	7.2	6.9	3.4	4.2	*0.7*	4.3	0.9	7.0	4.4	*0.2*	6.1	7.5	6.7	6.9	—	2.6	6.9	6.7
550-500	8.6	8.9	7.5	10.8	6.1	5.1	8.9	7.3	9.4	10.5	9.3	8.2	5.7	6.5	*1.7*	6.0	6.9	5.7
600-550	9.0	6.7	8.1	9.3	9.7	7.1	9.0	7.7	9.0	7.0	5.5	5.4	7.7	3.9	8.0	6.6	6.6	6.3
(c) Jodhpur																		
350-300	—	6.3	—	4.6	8.2	7.0	9.4	9.0	6.5	7.1	7.1	8.0	9.0	7.8	4.1	7.8	—	4.7
400-350	6.4	5.5	6.6	6.5	5.3	9.7	8.4	7.3	7.3	4.9	4.3	6.7	11.1	8.9	8.6	7.3	—	8.2
450-400	3.6	6.2	3.2	3.8	6.9	3.4	7.7	5.6	7.7	7.7	10.5	6.2	*—2.3*	6.7	6.6	8.2	—	6.6
500-450	7.7	3.1	4.5	2.4	*—1.6*	*1.2*	3.5	6.8	6.5	5.2	*1.4*	4.2	3.1	*0.6*	3.2	3.0	—	5.8
550-500	8.5	7.2	6.0	6.1	6.1	6.2	*—1.0*	4.8	4.4	6.7	*1.3*	*0.5*	*0.6*	7.6	3.3	6.0	—	5.4
600-550	5.4	6.8	5.7	7.3	9.6	7.3	7.8	5.3	2.7	4.4	4.2	6.9	9.0	4.1	3.6	*0.0*	—	7.6
(d) Lucknow																		
350-300	6.7	6.2		7.4	7.3	7.6	5.3	8.1	8.0	6.2	7.9	8.6	7.7	8.4	8.1	7.3	7.2	5.2
400-350	5.5	4.6		7.3	7.4	8.4	4.7	8.3	8.4	7.0	8.3	7.8	9.3	8.0	7.2	9.0	7.2	4.4
450-400	4.3	4.3		5.7	4.6	11.2	4.3	6.2	4.2	6.8	3.6	7.0	5.8	3.4	5.8	4.6	5.1	2.9
500-450	6.1	4.1		2.3	*1.1*	*1.1*	4.1	3.2	4.2	*—2.0*	2.7	*0.7*	*0.6*	4.5	4.6	4.7	*—1.7*	5.6
550-500	6.0	8.3		3.8	*1.4*	*—0.3*	*2.0*	*0.0*	*0.2*	6.3	*—1.1*	7.0	*2.0*	5.1	5.4	4.9	5.8	7.0
600-550	4.8	6.6		6.5	9.4	10.5	4.6	8.1	6.6	5.3	8.6	3.1	5.4	5.6	1.8	5.0	8.1	3.8

Lapse rate ≤2.0°C/km are shown in italics.

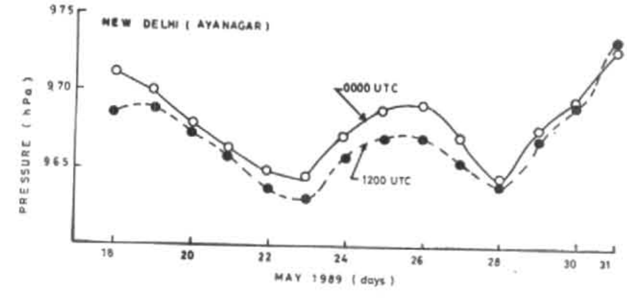


Fig. 4. Variation of station level pressure

3.2. *Dissipation of temperature inversion*

The conditions for dissipation of the temperature inversion became favourable by 00 UTC of 24 May 1989. The anti-cyclones at 300 hPa and aloft moved away from over Delhi and adjoining areas as shown in Fig. 3 (d) and 3 (e).

A trough in westerlies at 300 hPa was positioned along 74° E at 00 UTC on 24 May 1989 as seen in Fig. 3(d), and Delhi and neighbourhood was located under the forward region of this trough. In addition to these features, Delhi and adjoining areas were lying under and close to the left exit regions of the sub-tropical jet stream as evident in Fig. 3(f). Under the influence of these synoptic features, the subsidence vanished and the temperature inversion got broken subsequently. Fig. 4 viewed in relation to Fig. 2 also supports that the moving away of anti-cyclone aloft alone does not lead to the dissipation of mid-tropospheric stable layer. Even though the anti-cyclone has moved away on 23 May 1989, the dissipation of stable layer has occurred on 24 May 1989, when jet stream and trough in westerlies were also favourably positioned as explained earlier.

3.3. *Mid-tropospheric thermal inversion and heat wave*

Considering only areas in the neighbourhood of Delhi, the daily weather reports for Delhi, Chandigarh, Punjab, Haryana, Himachal Pradesh and Jammu & Kashmir, Rajasthan and Uttar Pradesh reveal the following facts:

(*i*) *Before formation of inversion* (*18 to 20 May 1989*)

Heat wave conditions prevailed in Rajasthan, parts of Haryana and Punjab. Day temperature were above normal in parts of Haryana, Punjab and normal in Rajasthan.

(*ii*) *During the period of inversion* (*21 to 24 May 1989*)

Heat wave conditions prevailed in parts of Punjab and Haryana and plains of Uttar Pradesh. Heat wave conditions prevailing in Rajasthan became severe on 22 May 1989 in most parts of Rajasthan. Day temperature also rose in Delhi and neighbourhood.

(*iii*) *After the break of inversion* (*25 to 31 May 1989*)

Heat wave condition abated from Haryaya, Punjab and Rajasthan. Day temperature also fell appreciably on 25 May 1989 over the region.

Heat wave conditions, therefore, appear to get strengthened with the persistence of the mid-tropospheric inversion.

4. Conclusion

Mainly anti-cyclonic circulation at higher level (300 hPa and aloft) favoured with location of trough and jet stream have been the main reason for subsidence and in turn the formation of mid-tropospheric inversion. Such events are not frequently observed during summer months. However, occurrence of such mid-tropospheric stable layer is possible under favourable conditions in a limited region and can be clearly seen in radiosonde profiles. Presence of localised mid-tropospheric in version cause discontinuity in the contours of geopotential and isotherm as drawn in synoptic charts. Such anomalous data is to be looked into carefully as it may be useful clues for short range local weather forecasting.

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