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Results of stratwarm campaign during winter of 1985-86

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The effect of the high latitude stratospheric warmings on low latitude middle atmosphere during the winter of 1985-86 has been studied on the basis of experiments conducted under Indo-Soviet Collaborative Programme. During this winter, two 'minor' warmings occurred in the high latitude middle atmosphere during mid-January and mid-February. The occurrence of cooling in the stratosphere and the lower mesosphere over Thumba simultaneously with the first warming event over the high latitudes has been observed. The second minor warming event is found to be associated with a cooling in the middle stratosphere over Thumba. A warming in the upper stratosphere and the lower mesosphere is observed over Thumba in the weakening stage of the second warming event. In association with the minor warmings over the high latitudes, there were short-period (i) strengthening of the easterly shear and weakening of the westerly shear in the high latitude stratosphere and lower mesosphere, and (ii) strengthening of the westerly shear in the lower mesosphere and of easterly shear in the upper stratosphere and the middle stratosphere over the two tropical stations.

1 Introduction

Sudden stratospheric warming is an extreme manifestation of dynamical processes in the middle atmosphere of high and middle latitudes during winter. This phenomenon results from the interaction of the ultra-long planetary waves of wave number 1 and/or 2 with the mean zonal flow in the stratosphere. The knowledge of the stratospheric warmings has been immensely developed in the past two decades primarily by (i) a vastly improved observational framework, including satellites observations of both hemispheres and (ii) theoretical insights gained by dynamical modelling. Comprehensive descriptions of the results of observational and recent model simulation studies have been reported by many workers[1-10]. Much work has not been done on the tropical middle atmosphere. The study of the behaviour of temperature and wind fields of the tropical middle atmosphere, therefore, forms an important part of the Indian Middle Atmosphere Programme (IMAP and IMAP-C) undertaken during 1982-89. As a part of this study, the characteristics of temperatures and winds of tropical middle atmosphere and their association with the dynamical events (stratwarm) observed over the high latitudes during winter are being investigated regularly using the weekly rocketsonde data from Thumba (lat., 8.5°N; long., 76.9°E) and Balasore (lat., 21.5°N; long., 86.9°E). Earlier studies have shown evidences of occurrence of strong perturbations in temperature and wind fields of tropical middle atmosphere during the winters[11-17]. Conducting an experiment was first contemplated by IMAP during the winter 1983-84. This programme could not be undertaken due to non-availability of the additional rockets during the campaign period. However, using the weekly rocketsonde data for both Thumba and Balasore, a scientific paper was brought out which highlighted the conditions of the tropical middle atmosphere during the winter 1983-84 (Ref. 16). Winter in Northern Europe (WINE), an international middle atmosphere programme, was also in progress during this period.

2 Experimental background

In order to study the tropical response to the perturbations over the high latitude middle atmosphere, a comprehensive programme for conducting stratospheric warming experiment from Thumba during the winter 1985-86 was planned under IMAP. To pursue this programme a provision to launch 10 additional M-100 rockets was initially planned. The State Committee for Hydrometeorology and Control of Natural Environment (SCHCNE) of

USSR agreed to allot 10 additional rockets under ISRO-SCHCNE collaborative programme in Theme-1. This Theme deals with Identification of Climatic Norms and Variability for the Middle Atmosphere" under ISRO-SCHCNE collaboration in space meteorology and aeronomy. A plan was chalked out to launch these rockets from Thumba as soon as a signal for the occurrence of major warming was reported over the polar region. Launchings associated with the major warming were scheduled on every Monday and Friday which had to be extended to every Tuesday and Thursday during the peak phase of the major warming so that the data for the entire period of an event could be monitored with an interval of 1-2 days. Since SCHCNE was interested to launch 7 rockets on Monday to keep their launch schedule with other Soviet stations, Heiss Island (lat., 81°N; long., 53°E) and Volgograd (lat., 49°N; long., 44°E), and the remaining 3 rockets in association with the warming event, the original schedule for rocket launchings could not be achieved. As suggested by SCHCNE the first Monday launching commenced on 20 Jan. 1986 which was associated with the occurrence of a minor warming. In all, 8 additional M-100 rockets were launched during the two minor warming events. All the additional launchings were successful except missing of chaff wind data in one of the launchings. Table 1 gives the details of M-100 rockets that were launched from Thumba during the period of two minor warming events.

3 Middle atmospheric conditions

3.1 Conditions prevailing over high latitudes

The meteorological conditions prevailing over the high latitude middle atmosphere during the winter 1985-86 were obtained from the stratalert message received daily through WMO Telecommunication channel during 1 Dec. 1985-26 Mar. 1986. The conditions of the middle atmosphere could be divided into 6 broad stages as mentioned below:

(i) Quiet conditions and presence of cold polar vortex during 1 Dec. 1985-Jan. 1986.

(ii) Disturbed midwinter conditions during 13-24 Jan. 1986. A minor warming also occurred during this period.

(iii) Undisturbed midwinter conditions revived during 24 Jan.-7 Feb. 1986.

(iv) Occurrence of another minor warming during 8-21 Feb. 1986.

(v) Establishment of quiet late winter conditions during 22 Feb.-2 Mar. 1986.

(vi) Occurrence of a minor warming again during 3-12 Mar. 1986.

Table 1 – Details of M-100 rocket launching from Thumba during period of two minor warming events during Jan.-Feb. 1986
[Asterisks (*) indicate days of additional launchings]

Launch number	Day/Date	Time hrs IST	Data availability layer (km)			Remarks
			Wind (Parachute)	Wind (Chaff)	Temperature	
08.845	Wednesday/8.1.86	1737	12-60	60-85	12-85	Weekly launchings are conducted on
08.846	Wednesday/15.1.86	1645	12-58	58-76	12-82	every Wednesday.
08.847	Monday/20.1.86	1630	12-59	59-83	13-79*	In case of launch
08.848	Wednesday/22.1.86	1630	12-58	58-84	12-83	failure, flights are
08.849	Fiday/24.1.86	1800	12-59	59-70	12-83*	taken on next day.
08.850	Monday/27.1.86	1714	12-58	58-76	12-80*	
08.852	Thursday/30.1.86	1630	12-60	72-80	12-76*	
08.853	Monday/03.2.86	1800	12-57	57-80	12-77*	
08.854	Wednesday/05.2.86	1635	12-57	57-80	12-77	
08.855	Thursday/13.2.86	2000	24-57	57-81	24-76	
08.856	Monday/17.2.86	1705	12-60	No data	12-80*	
08.858	Thursday/20.2.86	1730	12-56	56-85	12-85	
08.859	Friday/21.2.86	1917	12-60	60-79	12-79*	
08.860	Monday/24.2.86	1917	12-60	60-83	12-77*	
08.861	Thursday/27.2.86	1707	12-58	58-80	12-76	
08.862	Wednesday/05.3.86	1707	22-58	58-80	22-76	

This late minor warming ultimately developed into the final warming, ushering the approach of the summer condition in the northern middle atmosphere.

3.2 Conditions prevailing over tropical and high latitude middle atmosphere during the two minor warming events

To examine the effect of high latitude warming on the tropical middle atmosphere, the time-height cross-sections of temperatures and those of zonal and meridional winds for Thumba, Volgograd and Heiss Island for the period Jan.-Mar. 1986 were constructed using the rocket data received from the Central Aerological Observatory, Moscow, USSR and are shown in Figs 1-3. The stratopause level for each station, which is shown by the broken line in Fig. 1 is drawn on the basis of the actual data. Time-sections of temperatures based on the deviations from the seasonal mean (December 1985-February 1986) are also presented in Fig. 4 for the three stations. Rocket wind data for January and February were also utilized [Figs 5(a) and 5(b)] for constructing two time-sections of winds. Two time-sections of the average temperature deviations from the seasonal mean for the layer of 25-40 km thickness for Thumba, Volgograd and Heiss Island for the two minor warming events are also shown in Fig. 6. Actual magnitudes of warmings/coolings and the levels at which they occurred are obtained directly from the rocketsonde data available for Thumba, Volgograd and Heiss Island. These data are not reproduced here for brevity. The arrow marks in the abscissae of Figs 1-5 indicate the dates of weekly as well as additional rocket launchings. In Fig. 6 arrow marks are not shown.

4 Temperature characteristics

4.1 During first minor warming event (13-24 Jan. 1986)

At Thumba warming occurred in the upper stratosphere; the maximum warming was 18°C at 45 km on 15 January over a period of 7 days. Almost the entire stratosphere and the mesosphere were cooler on 20 January (day of an additional flight) and the maximum cooling was 14°C at 65 km on that day. A cooling was also noticed in the lower stratosphere on 20 January; it was up to 12°C at 28 km over a period of 5 days. A temperature rise of 13°C in the altitude range 63-69 km with a peak of 14°C at 65, 67 and 68 km, over a period of 2 days, was observed on 22 January. This period was associated with the minor warming in the high latitudes. Figs 1(a) and 4(a) show the temperature variability over Thumba.

At Volgograd the stratopause was warm and the maximum warming was 16°C at 45 km on 15 Jan. over a period of 2 days and it was 13°C at 52 km on 20 Jan. over a period of 5 days. A rise of temperature was also noticed in the lower stratosphere on 20 January; it was up to 22°C at 25 km over a period of 5 days. A strong cooling up to 33°C around 70 km altitude was concurrently noticed on 20 Jan.

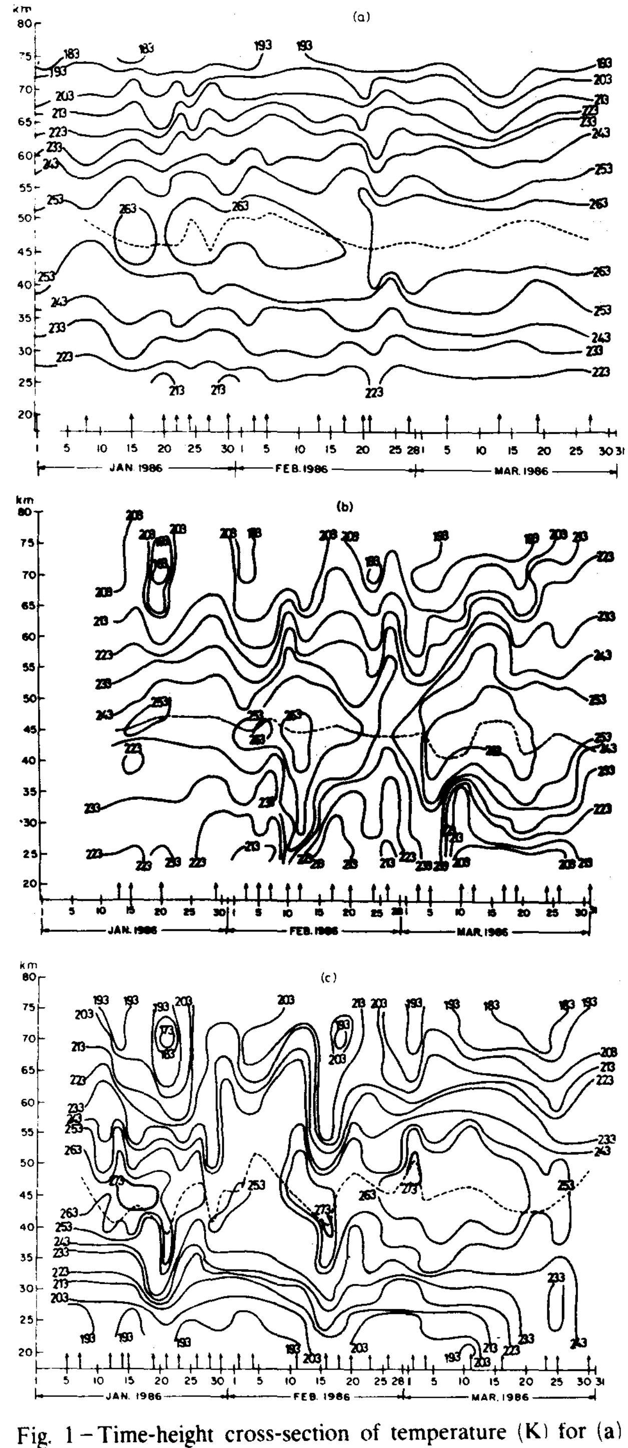

Fig. 1 – Time-height cross-section of temperature (K) for (a) Thumba, (b) Volgograd and (c) Heiss Island during Jan.-Mar. 1986 (Isolines are drawn at an interval of 10 K. Broken lines indicate stratopause.)

with the warming in the stratosphere. Afterwards a warming up to 31°C in the mesosphere at around 70 km occurred on 29 Jan. over a period of 9 days. Figs 1(b) and 4(b) show the temperature variability over Volgograd.

At Heiss Island a strong cooling up to 27°C in the lower mesosphere (54-57 km) was noticed on 15 Jan. over a period of 1 day. A strong warming up to 63°C was noticed in the middle stratosphere (~ 35 km) on 19 Jan. over a period of 4 days with con-

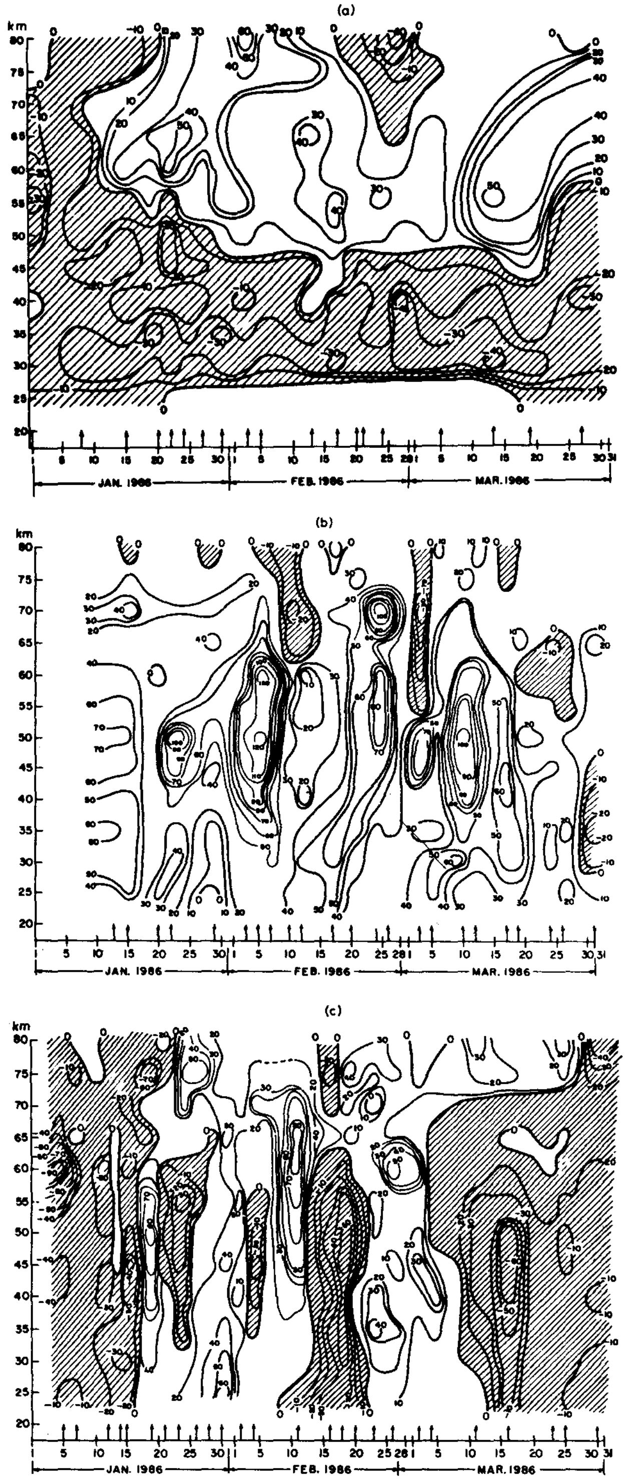

Fig. 2 – Time-height cross-section of zonal wind (mps) for (a) Thumba, (b) Volgograd and (c) Heiss Island during Jan.-Mar. 1986 (Hatched portions indicate easterly wind.)

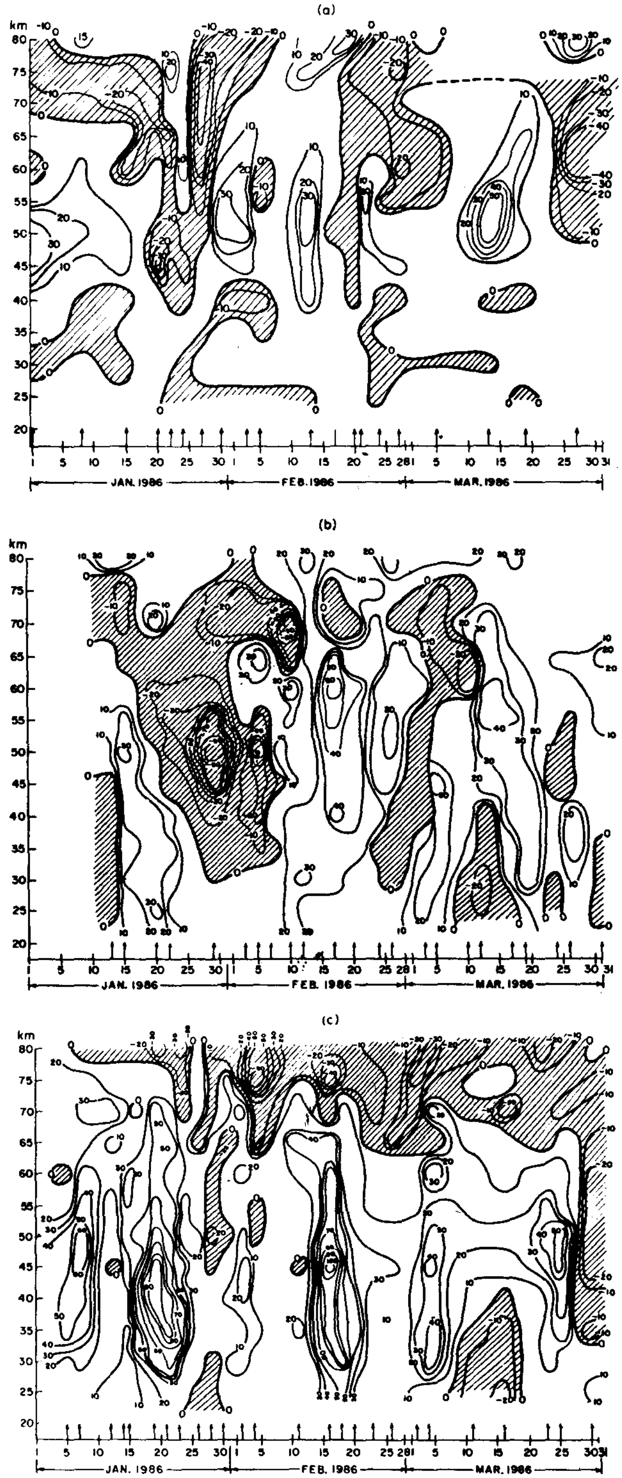

Fig. 3 – Time-height cross-section of meridional wind (mps) for (a) Thumba, (b) Volgograd and (c) Heiss Island during Jan.-Mar. 1986 (Hatched portions indicate northerly wind.)

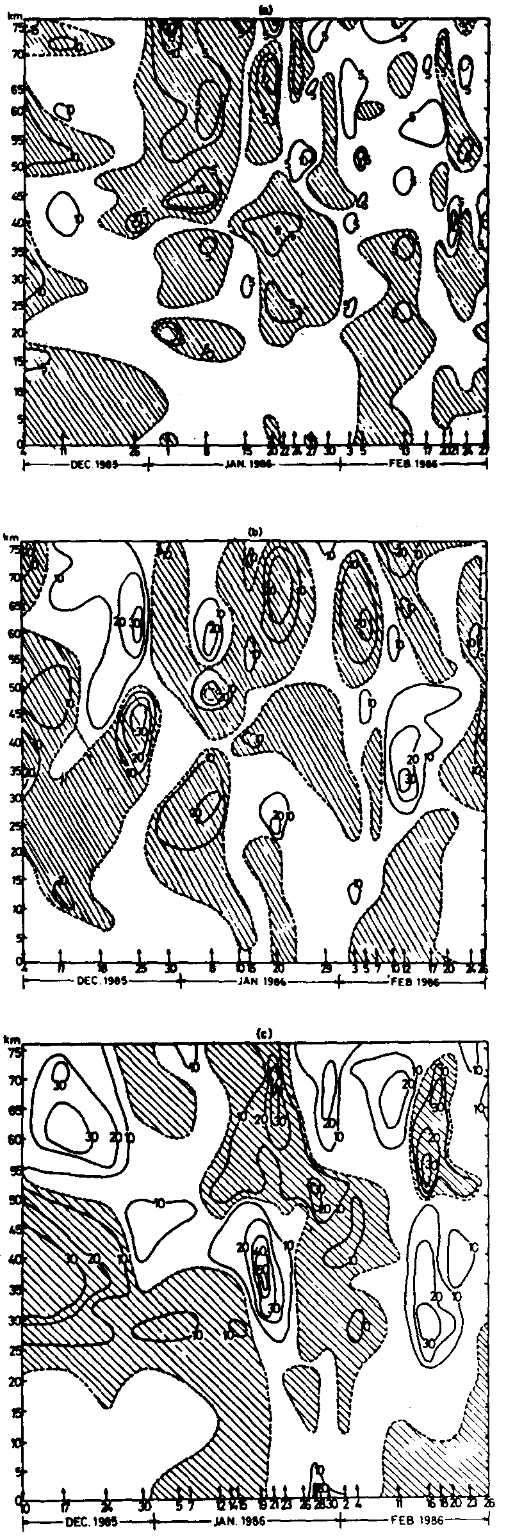

Fig. 4 – Time-height cross-section for temperature (K) as deviation from the December 1985-February 1986 mean for (a) Thumba (Isolines are drawn at an interval of 5K deviation), (b) Volgograd (Isolines are drawn at an interval of 10K deviation) and (c) Heiss Island (Isolines are drawn at an interval of 10K deviation) (Hatched portions indicate negative departures.)

current cooling in the mesosphere at 62 km and upward. The cooling further intensified up to 29°C at 68 km altitude on 21 Jan. Strong cooling was also observed concurrently in the upper and the middle stratosphere on the same day, the maximum cooling being 37°C at 41 km over a period of 2 days. The perturbations subsided afterwards on 29 Jan. Figs 1(c) and 4(c) show the temperature variability over Heiss Island.

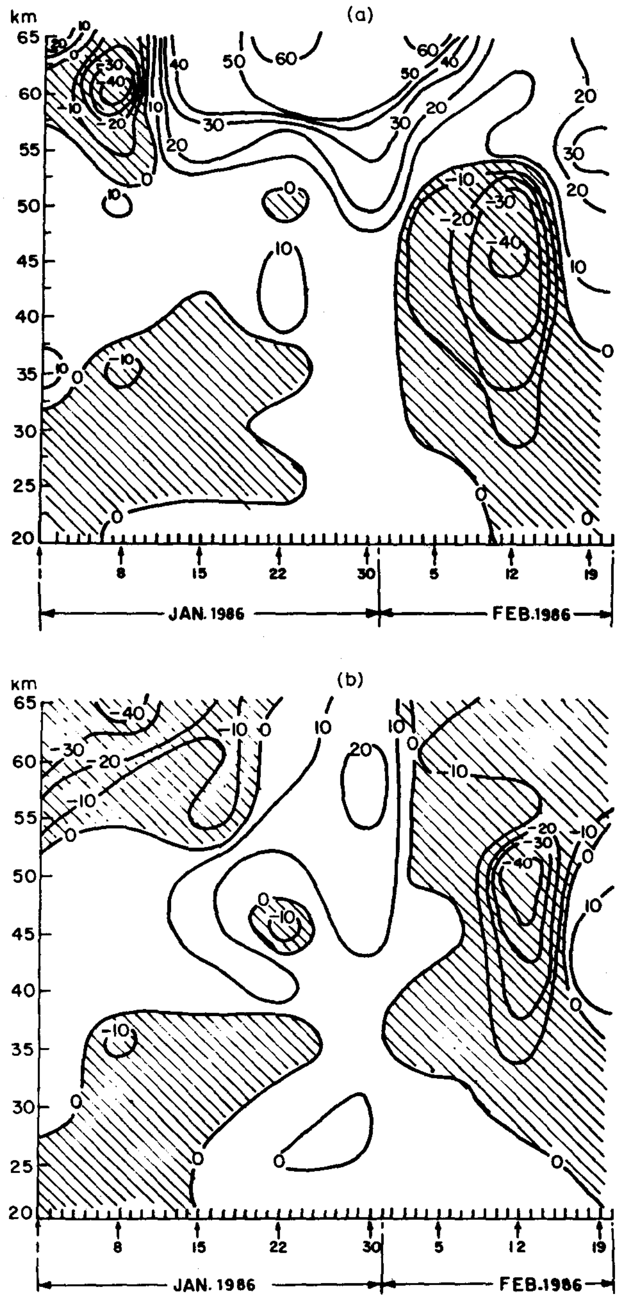

Fig. 5 – Time-height cross-section of (a) zonal wind (mps) and (b) meridional wind (mps) for Balasore during January-February 1986 [Hatched portions indicate easterly wind for (a) and northerly wind for (b).]

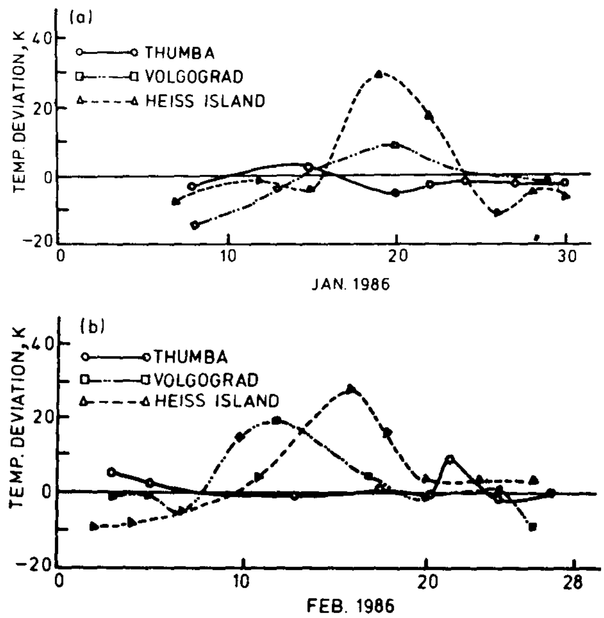

Fig. 6 – Time variation of the temperature (average for 25-40 km altitude layer) for Thumba, Volgograd and Heiss Island during the period of (a) January warming event and (b) February warming event [Temperatures are drawn based on the deviations from the seasonal mean (December 1985-February 1986).]

4.2 During second minor warming event (8-21 Feb. 1986)

At Thumba on 13 February the temperature in the middle stratosphere (31-35 km) was low with a cooling up to 7°C at 34 km over a period of 8 days. A warming was also noticed in the mesosphere (59-72 km) on 17 February; the warming was up to 7°C on that day over a period of 4 days. A warming was noticed in the middle and the upper stratosphere on 21 Feb. (day of an additional flight) with a temperature rise up to 16°C at 42 km over a period of 1 day. In the lower mesosphere (52-63 km), a concurrent cooling up to 14°C at 60 km was also noticed on 21 February during the same interval. This was followed by a cooling almost in the entire stratosphere and the lower mesosphere up to 54 km; the cooling on 24 February was up to 19°C at 42 km over a period of 3 days. The temperature variability over Thumba during the second warming event could be noticed from Figs 1(a) and 4(a).

At Volgograd there was cooling in the entire mesosphere on 3 February; the cooling was up to 22°C at 76 km over a period of 5 days. Afterwards a strong warming was noticed in the stratosphere; the temperature rise was up to 28°C at 40 km on 10 February over a period of 3 days and up to 19°C at 30 km on 12 February over a period of 2 days. On 17 February the warming subsided and a cooling prevailed in the stratosphere; the cooling was up to 30°C at 32 km over a period of 5 days. The cooling propagated upwards into the entire mesosphere on 24 February, when a cooling up to 19°C around 60 km over a period of 4 days was noticed. This was followed by a warming up to 27°C in the same region on 26 February over a period of 2 days. On 3 March a cooling in the same region around 60 km was noticed. The above feature generated a wavy structure in the temperature field with a period of about 2-5 day, which could also be noticed from Figs 1(b) and 4(b).

At Heiss Island a warm middle stratosphere with a warming up to 19°C at 37 km and a cold upper stratosphere with a cooling up to 20°C at 43 km over a period of 2 days were noticed on 4 February. On 11 February, almost the entire middle atmosphere was warm; the warming was up to 32°C at 45 km and at 68-69 km over a period of 7 days. The warming in the stratosphere continued up to 16 February and it was up to 31°C at 39 km over a period of 5 days. This feature was concurrently associated with a cooling up to 42°C in the mesosphere (52-54 km) on the same day during the same interval. The temperature profile on 20 February showed opposite characteristics, i.e. the cooling in the stratosphere up to 19°C at 27 km and the warming in the mesosphere up to 27°C at 56 km over a period of 2 days, the previous launching being taken on 18 February. On 23 February warmings up to 21°C at 71 km over a period of 3 days and up to 39°C at 70-71 km over a period of 5 days were noticed. This was concurrently associated with the cooling in the lower stratosphere. A wavy pattern in the temperature field could also be noticed at Heiss Island from Figs 1(c) and 4(c) as observed at Volgograd.

5 Zonal wind characteristics

5.1 During first warming event (13-24 Jan. 1986)

At Thumba [Fig. 2(a)] around 20 January the easterly component strengthened in the middle stratosphere (30-35 km) and westerly component in the mesosphere (around 65 km).

At Volgograd [Fig. 2(b)], around 20 January strong westerly wind dominated in the region ranging from the middle stratosphere to the middle mesosphere. Very strong wind of magnitude 100 mps from the west was noticed at 55 km.

At Heiss Island [Fig. 2(c)], the strong easterly wind, prevailing in the stratosphere and the lower mesosphere, reversed to strong westerly on 19 January. The strong westerly wind then reversed to strong easterly in the 35-60 km region. The strong easterly shear in the wind field was associated with the period of the peak and the weakening of the minor warming.

At Balasore [Fig. 5(a)], strengthening of the westerlies in the lower mesosphere, which was concurrently associated with weakening of the westerlies in the entire stratosphere, was noticed during the minor warming period.

5.2 During second warming event (8-21 Feb. 1986)

At Thumba [Fig. 2(a)], the strong westerly was observed from 13 February onwards in the middle mesosphere and continued up to 24 February. The westerly shear increased in the mesosphere (55-70 km) from 3 to 13 February. Maximum wind of 40 mps was observed around 65 km on 13 February. Easterly component dominated in the upper stratosphere and downwards.

At Volgograd [Fig. 2(b)], the westerly wind was also strong in the entire middle atmosphere during the same period. Wind was very strong (about 80 mps) at 55 km altitude and 100 mps at 70 km altitude. Strongest wind of magnitude 100 mps at 50 km was reported on 5 February.

At Heiss Island [Fig. 2(c)], the zonal wind was strong easterly in the entire stratosphere and in the lower mesosphere with the peak value of 50 mps around 50 km on 20 February. The warming period was followed by the westerly wind from 24 February till the commencement of the final warming.

At Balasore [Fig. 5(a)], strong westerlies were noticed in the lower mesosphere during the period of minor warmings. The easterlies prevailed in the middle and the upper stratosphere which enhanced to a magnitude of 40 mps during this period.

6 Meridional wind characteristics

6.1 During the first warming event (13-24 Jan. 1986)

At Thumba [Fig. 3(a)], the northerly wind prevailed in the mesosphere (70-80 km) during the first half of January which propagated dowward in the stratosphere up to 35 km on 20 January.

At Volgograd [Fig. 3(b)], the same characteristics of the meridional wind was observed as noticed at Thumba, but the magnitude of meridional component was three fold more at Volgograd.

At Heiss Island [Fig. 3(c)], the meridional flow was southerly unlike that noticed at Volgograd and Thumba. A maximum southerly wind of 90 mps was observed at 45-50 km on 21 January.

At Balasore [Fig. 5(b)], the northerly wind was noticed in the lower mesosphere up to the third week of January.

6.2 During the second warming event (8-21 February)

At Thumba [Fig. 3(a)], the southerly wind prevailed in the region 45-80 km during 30 January to 17 February; peak value was around 30 mps on 13 February. There was a reversal of the southerly wind to the northerly during the period of the peak intensity of the warming.

At Volgograd [Fig. 3(b)], the southerly wind (in the region of 20-65 km) prevailed during the period 7-20 February. The southerly reversed to the northerly from 20 February in the stratosphere and from 25 February in the lower mesosphere. The northerly wind continued up to 3 Mar. 1986.

At Heiss Island [Fig. 3(c)], the strong southerly component prevailed in the entire stratosphere and in the mesosphere up to 70 km from 1 February to 7 March. A very strong southerly wind of 100 mps was noticed around 45 km altitude on 16 February.

At Balasore [Fig. 5(b)], the northerly component was noticed from 5 to 19 February on the middle stratosphere and in the lower mesosphere. The peak in the northerly was about 40 mps at the stratopause region on 12 February.

7 Discussion

During the winter of 1985-1986, no major warming was observed over the high latitudes. Two prominent minor warmings, however, occurred during 13-24 Jan. and 8-21 Feb. 1986. The first warming event was more intense over Heiss Island than over Volgograd. The centre of the warming layer was at a higher altitude at Heiss Island by about 10 km than at Volgograd [Figs 4(b) and 4(c)]. During the second event, the intensity of the warming was almost same at both the stations. But the centre of the warming layer was at higher altitude at Volgograd by about 5 km. At Heiss Island the stratopause [indicated by broken lines in Fig. 1{(a)-(c)}] descended at a lower level up to around 40 km during the period of the two minor warmings. Descending of the stratopause, however, was not observed either at Volgograd or at Thumba during the above periods.

The entire middle atmosphere over Thumba responded to the temperature variations at higher latitudes during the periods of the minor warmings. During the first minor warming event the cooling was dominant throughout the entire middle atmosphere over Thumba [Fig. 6(a)]; but it was not so during the second event. A warming pulse was observed over Thumba just after the occurrence of the second warming event [Fig. 6(b)]. This warming pulse over Thumba could be associated with the late winter condition that prevailed over high latitudes after 22 Feb. [Sec. 3.1(v)]. The second minor warming event that occurred in the high latitudes during 8-21 February was associated with a minor cooling on 13 February over Thumba over a period of 8 days [Fig. 6(b)]. The magnitude of the cooling ranged from 4 to 9°C in the region of 32-38 km (obtained by comparing actual rocketsonde temperature data for 5 and 13 Feb. which are not shown in the text). The cooling observed in 32-38 km on 13 Feb. was above the noise level since the mean square error in determining the atmospheric temperature in this height range is not above 3°C (Ref. 11). Spring changeover of the circulation pattern in the high latitudes occurred after 12 March.

A study of the radiance measurements from Nimbus 3 satellite by Fritz and Souless[18] revealed, for the first time, that the stratospheric warmings in the high latitudes of the winter hemisphere were accompanied by simultaneous cooling in the stratosphere of the tropics and of the summer hemisphere. Also, the atmosphere appears to act like a standing wave in which the amplitudes of the temperature changes are larger in the middle and high latitudes of the winter hemisphere than in the tropics and summer hemisphere. The peak phase of the cooling at Thumba during the first event was associated with the peak phase of the warming at Volgograd and Heiss Island during 19-20 January [Fig. 6(a)]. This feature was associated with cooling in the mesosphere at Heiss Island and Volgograd, and warming in the upper mesosphere over Thumba. This is in conformity with the suggestion given by Lordi *et al.*[19] from their theoretical consideration, that at high latitudes stratospheric warming is associated with mesospheric cooling which in turn is associated with mesospheric warming and stratospheric cooling at low latitudes. Strengthening of the easterly shear at Heiss Island in the stratosphere and weakening of the westerly shear at Volgograd in the stratosphere and lower mesosphere during the peak and weakening phase of the warming were observed. But at Balasore weak zonal wind in the stratosphere and strong westerly shear in the lower mesosphere prevailed during the peak and weakening phase of the warming. At Thumba there were strengthenings of the easterlies in the stratosphere and of the westerlies in the mesosphere during the same period (Fig. 2). Strong southerly components in the stratosphere and lower mesosphere were noticed in both the high latitude stations. The northerly components were prevalent in the lower mesosphere at Balasore and in the upper stratosphere and mesosophere at Thumba during the first event. The northerly components were also dominant in the middle and the upper mesosphere at Volgograd when strong cooling was noticed in that region concurrently in association with the minor warming. The above results suggest that the first event had affected the wind field over both the high latitude stations where weakening of the westerly shear occurred temporarily. Over the tropics the prevailing westerly winds in the lower mesosphere further strengthened in association with the cooling.

The peak phase of warming at Thumba during the second event was preceded by the peak phase of warming at Heiss Island by about 5-6 days and the peak phase of warming at Heiss Island was then preceded by the peak phase of warming at Volgograd by about 3-4 days [Fig. 6(b)]. During the second event the easterly regime prevailed over Heiss Island and the westerly shear weakened over Volgograd in the stratosphere and lower mesosphere. At Balasore, there was strengthening of the easterlies in the stratosphere. At Thumba the easterly regime prevailed in the lower and middle stratosphere, whereas there was weakening in the westerly regime in the upper stratosphere and lower mesosphere during the weakening phase of the event. Strong southerly component in the stratosphere and lower mesosphere was noticed at both Heiss Island and Volgograd. But strong northerly shear prevailed in the stratosphere and mesosphere at both Balasore and Thumba. It was also reported from the daily stratalert messages that the second warming event was associated with the reversal in both the temperature gradient and the wind in the mesosphere downward up to 1 mbar level for 2-3 days after the weakening phase of the minor warming, which was not so in case of the January event. Also the presence of the strong westerlies in the vicinity of the polar night jet (Volgograd) during the winter of 1985-86 could suppress the vertical propagation of the ultra-long planetary waves and hinder weakening of the polar night jet preventing the wind reversal poleward (of 60°N), the condition necessary for the development of a major warming.

8 Conclusions

The results of stratwarm experiment conducted during the winter of 1985-86 have revealed the following.

(i) Two dominant minor warming events were observed during mid-January and mid-February in the winter of 1985-86. During mid-January warmings were observed in the stratosphere both at Heiss Island and Volgograd, which were concurrently associated with cooling over Thumba. During mid-February a warming was observed at Heiss Island which was preceded by a warming at Volgograd without showing any significant change at Thumba. At Heiss Island stratopause descended during the peak intensity of warmings.

(ii) During the first minor warming event, coolings up to 12°C in the lower stratosphere as well as up to 14°C in the middle mesosphere over a period of 5 days were concurrently noticed at

Thumba. This feature was followed by a warming up to 14°C in the middle mesosphere over a period of 2 days (obtained by comparing data for two launchings on 20 and 22 January).

(iii) During the second minor warming event, conditions for development of a major warming in the mesosphere downward up to 1 mbar also prevailed over the polar regions. During the weakening phase of the minor warming, a temperature rise up to 16°C in the upper stratosphere with a concurrent temperature fall up to 14°C in the lower mesosphere over a period of 1 day took place at Thumba (obtained by comparing data for two successive launchings on 20 and 21 February).

(iv) A short-period strengthening in the easterlies at Heiss Island and Volgograd was associated with both the cases of minor warmings. Strengthening of westerly shear in the mesosphere and of easterly shear in the upper stratosphere and below were concurrently observed over Balasore as well as Thumba.

Since no major warming occurred during the winter of 1985-86, it is desirable to conduct another stratwarm experiment during the period of a major warming. The programme has to be planned in such a way that the additional rockets should be launched simultaneously from all the three stations (Heiss Island, Volgograd and Thumba). Similarly RH-200 rockets should also be launched from Balasore. Such a comprehensive programme will go a long way to enhance our present knowledge of the behaviour of the tropical middle atmosphere in response to the spectacular events occurring over the polar regions in the winter.

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