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Water vapour mixing ratio in the troposphere and its influence on the tropopause over India and neighbourhood

K. RAMAMURTHY

Meteorological Office Poona

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ABSTRACT. The distribution of water vapour mixing ratio in the troposphere over different stations in India and the three equatorial stations—Nairobi, Gan and Singapore—through the year has been studied with reference to the level of the tropopause over these stations to see if there is any relationship between these two elements. Meridional distribution of water vapour mixing ratio along longitudes 73° Eand 80°E during June and October has also been examined with reference to the tropopause level along these longitudes during these two months. In addition, the distribution of the mixing ratio and the level of tropopause during active and break monsoon spells during the years 1971 through 1973 has also been looked into. It is seen from these, that there is no unique or uniform relationship between the tropopause and water vapour mixing ratio over India and along the equator throughout the year.

1. Introduction

1.1. While examining the upper air temperatures of Gan (0° 41′ S, 73° 09′E) for the 9-year period 1962 through 1970 by the author, it was found that the lowest level of the tropopause (15·13 km) was reached during August over this station and the highest tropopause (16·75 km) in January, with the annual range of the order of 1·6 km. It is a well known fact that the highest tropopause (about 17 km) occurs over north India round about Lat. 27°N during July (peak of the summer monsoon period). A south-north upward slope of the tropopause occurs from the equator to north India during the northern summer, the slope being about 2 km over a latitudinal distance of 27 degrees. Godbole (1973), while dealing with the Numerical Simulation of the Indian Summer Monsoon, also showed that the computed tropopause height increased with latitude from south to north (during July). This variation of tropopause height with latitude was attributed to radiative processes. According to him, high latitudes over India during July have more amount of water vapour penetrating to greater heights than low latitudes, with the result that "cooling due to water vapour penetrates correspondingly to greater heights, pushing the tropopause upward over high latitudes". Godbole and Kelkar(1971) studied the individual effects of water vapour, carbon di-oxide and ozone on the Radiative Equilibrium of the atmosphere during July 1964-65 at 22·5°E, 80°N. They showed, *inter alia*, that water vapour plays the most dominant role in determining the radiative equilibrium of the troposphere and that an increase in the water vapour content always tends to raise the height of the tropopause. This was, according to them, "due to increased cooling effect, due to the increase considered in the water vapour, extending to higher levels, before being compensated by the heating due to ozone". Smith (1963), while presenting a Pole-to-Pole cross section of the tropopause height profile along the western longitudes, showed that the summer tropopause was *lower* than the winter tropopause in the northern hemisphere. While discussing the possible causes for the lower summer tropopause, he rejected the convection hypothesis on the ground that if convection controlled the lapse rate, the tropopause should be *higher* in summer when the convection was most active. At a majority of stations investgated by him, the tropopause was found to be lowest in summer months when rainfall was greatest although the release of latent heat should have caused the tropopause to rise. He inferred that the only possible factor which could cause a change in the tropopause height seemed to be water vapour. Sverdrup (1945) has shown that as temperature and humidity increase, the net emission of radiant energy from the surface of the earth back to space decreases and according to Smith (1963), this might be the cause for the tropopause to occur at a lower altitude in summer than in winter. He plotted the 1 gm/kg mixing ratio for the different months against height in respect of Cape Canaveral, Florida (28° 29′ N, 80° 33′ W) where also the summer tropopause was lower. He noticed that the fall of tropopause level in summer was synchronous with the summer rise in mixing ratio over

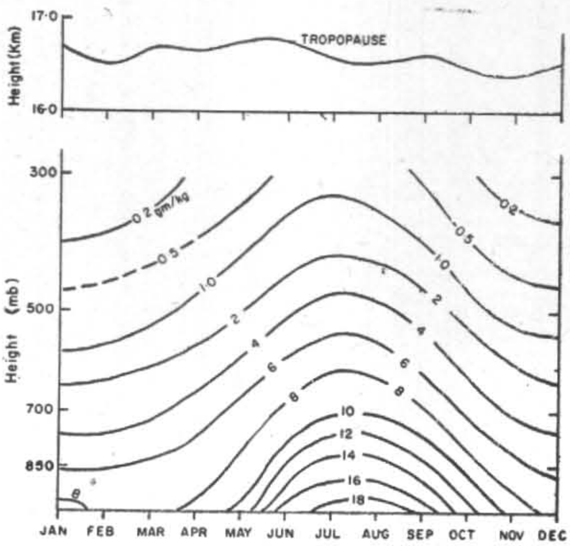


Fig. 1. Mean water vapour mixing ratio and tropopause height over Nagpur

TABLE 1

Mean water vapour mixing ratio (gm/kg) and height of tropopause over Gan

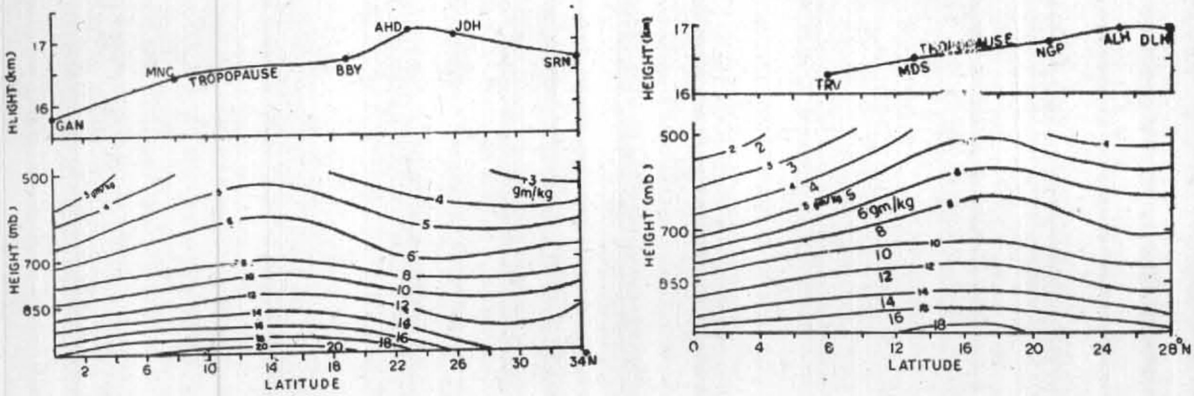
(Based on data for the years 1962 through 1970)

	Levels (mb)						Tropopause height (km)
	1000	850	700	500	400	300	
Jan	17·5	10·6	6·4	2·5	1·2	0·39	16·75
Feb	17·5	10·1	5·1	2·2	1·1	0·39	16·74
Mar	17·8	10·5	5·8	2·3	1·1	0·34	16·65
Apr	18·3	11·0	6·7	2·6	1·2	0·39	16·74
May	18·5	11·3	6·5	2·7	1·3	0·43	16·44
Jun	17·7	10·6	5·6	2·3	1·2	0·40	15·82
Jul	18·1	10·7	5·5	2·0	1·1	0·39	15·39
Aug	17·6	10·6	6·0	2·4	1·3	0·40	15·13
Sep	17·4	10·6	5·9	2·5	1·3	0·41	15·51
Oct	17·3	10·7	6·5	2·8	1·4	0·43	16·04
Nov	17·3	10·6	6·5	2·7	1·2	0·36	16·41
Dec	17·2	10·5	6·3	2·5	1·2	0·39	16·66

that station and therefore concluded that increase in water vapour might be the cause for the tropopause to occur at a lower altitude in summer than in winter. Sastry and Narasimham (1966) were of the view that Smith's conclusions were not applicable in respect of Indian stations north of Lat. 20°N during the summer monsoon. In our study mentioned at the beginning, we noticed that over Gan (0° 41′ S, 73° 09′E), while the tropopause was highest during January and lowest during August, the water vapour mixing ratio showed no variation at all in the lower, middle and upper troposphere as is evident from Table 1.

1.2. We have thus, two postulations (which contradict each other), *viz.*, (*i*) the tropopause height *decreases* due to increased moisture in the troposphere (Smith 1963) and (*ii*) the tropopause height *increases* due to increased moisture (Godbole and Kelkar 1971 and Godbole 1973). We wished to examine these two postulations in a more detailed manner, with particular reference to India and the immediate neighbourhood.

1.3. If we consider the summer monsoon alone, we have over India, high tropopause in the northern latitudes where the water vapour mixing ratio is



(a) Along 73°E

(b) Along 80°E

Fig. 2. Mean water vapour mixing ratio and tropopause height along 73°E and 80°E during June

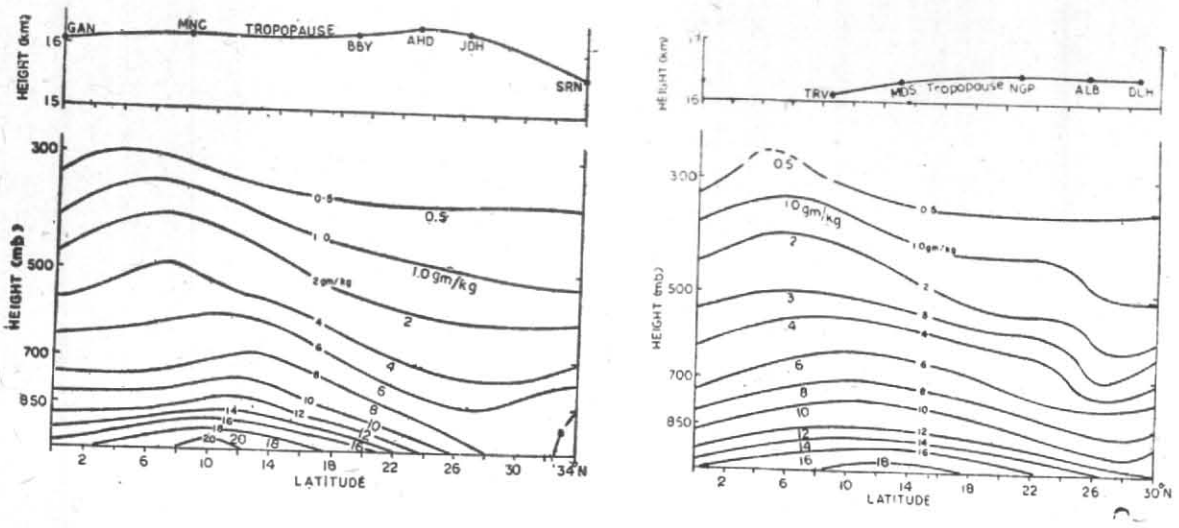
also high and low tropopause in the equatorial region where the water vapour mixing ratio is comparatively lower. There is, however, very little variation either in the dry bulb temperature or water vapour mixing ratio in the lower, middle and upper trpopospheres throughout the year over the equator (*e.g.*, Gan) though the tropopause comes down by as much as 1·6 km during August as compared to January. Hence, this inquiry, whether the water vapour mixing ratio has any role at all to play with reference to the height of the tropopause.

2. Discussion

2.1. Let us first consider the conditions throughout the year over Nagpur, the nearest station to 22·5°N, 80°E (the position considered by Godbole and Kelkar 1971). In Fig. 1, we have presented the mean distribution of water vapour mixing ratio for Nagpur from January through December. We have also shown the mean tropopause height for each month in this figure (The mixing ratios were worked out from the mean monthly dew point values published in the *Normals of Climat. Temp. based on morning and afternoon/evening RS data for the period 1951-1970*: India Met. Dep. 1972). The tropopause values in respect of Indian stations are those published by Sivaramakrishnan *et al.* (1972). We see from Fig. 1, that the highest tropopause occurs during May–June and the lowest tropopause during October–November. The highest mixing ratio occurs during July and the lowest in December. The mean mixing ratio at Nagpur during July is about 250 per cent more at 850 mb, 350% more at 700 mb, about 600% more at 500 mb and about 550% more at 300 mb as compared to December. There is hardly any difference in the level of the tropopause between July and December. Sharma (1966) who subjected the mean tropopause heights of Indian stations to Fourier Analysis, showed that the annual fluctuations of the tropopause heights are the least in the central regions of India (about 250 gpm). However, we notice vast changes in the mixing ratios during the course of the year over Nagpur.

2.2. We shall now examine the distribution of water vapour mixing ratio and tropopause height during June and October along the two meridians, 73°E and 80°E across India. June represents the monsoon conditions in the advancing phase and October, in the retreating phase. Figs. 2(a) and 2(b) contain the latitudinal distribution of mean mixing ratio during June along these two meridians across India. Similar information in respect of October along the same two meridians is given in Figs. 3(a) and 3(b). The mean heights of tropopause over stations at or close to these two meridians have also been shown in these figures. The features of these two figures are summarised in Table 2. From the above table, it would appear that the behaviour of the tropopause is independent of the water vapur mixing ratio in the troposphere during the Summer Monsoon (both in the advancing and retreating phases).

2.3. Let us now deal with the problem from another angle. We shall see the relationship between mixing ratio and tropopause during different months of the year at various latitudes of India. Figs. 4(a), 4(b) and 4(c) give the distribution of mixing ratio and mean tropopause height over Jodhpur, Delhi and Calcutta respectively. These three stations represent the northern latitudes of India. Over all these three stations, the tropopause



(a) Along 73°E (b) Along 80°E

Fig. 3. Mean water vapour mixing ratio and tropopause height along long. 73°E and 80°E during October

TABLE 2

Month	Figure	Meridian (°E)	Latitude at which highest mixing ratio occurs at 500 mb (°N)	Mean height of tropopause at the latitude of maximum mixing ratio at 500 mb (km)	Highest tropopause level along the meridian (km)	Latitude at which highest tropopause occurs (°N)	500 mb mixing ratio at the latitude of highest tropopause as compared to the amount at the latitude mentioned in column 4 (gm/kg)
June	2a	73	13	16·60	17·20	24	1·0 lower
June	2b	80	16	16·60	16·95	26	1·1 lower
October	3a	73	6	16·20	16·40	24	3·2 lower
October	3b	80	6	About 16·0	16·45	22	2·0 lower

reaches the highest level during the summer monsoon season. The mixing ratio is also highest during the months of July and August. The tropopause goes upwards with an increase and comes down with a decrease in moisture in the troposphere over these stations. Over Calcutta, it is not, however, so very apparent. The postulations of Godbole and Kelkar (1971) appear to fit in broadly with respect to these three stations (northern parts of India). Fig. 5 gives the information on tropopause and mixing ratio in respect of Bombay (Lat. 19° N) (We have already dealt with another central Indian station, *viz.*, Nagpur). The mixing ratio is maximum during July–August over Bombay. However, the highest tropopause occurs during March–May. The behaviour of the tropopause over Bombay appears to be indifferent with reference to the moisture below. Hence, in respect of

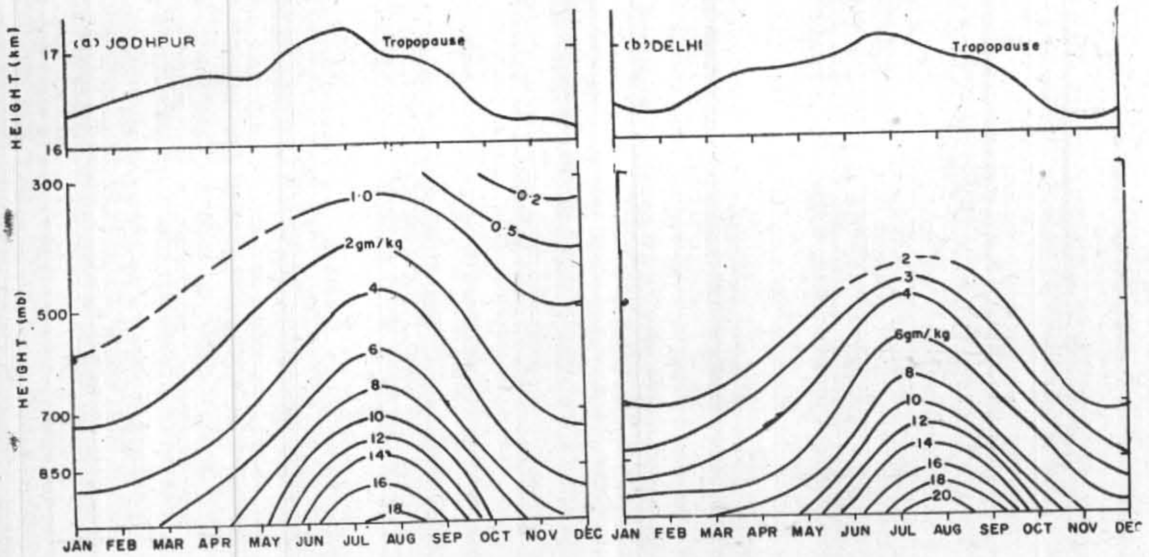


Fig. 4 (a). Jodhpur Fig. 4 (b). Delhi

Mean water vapour mixing ratio and tropopause height

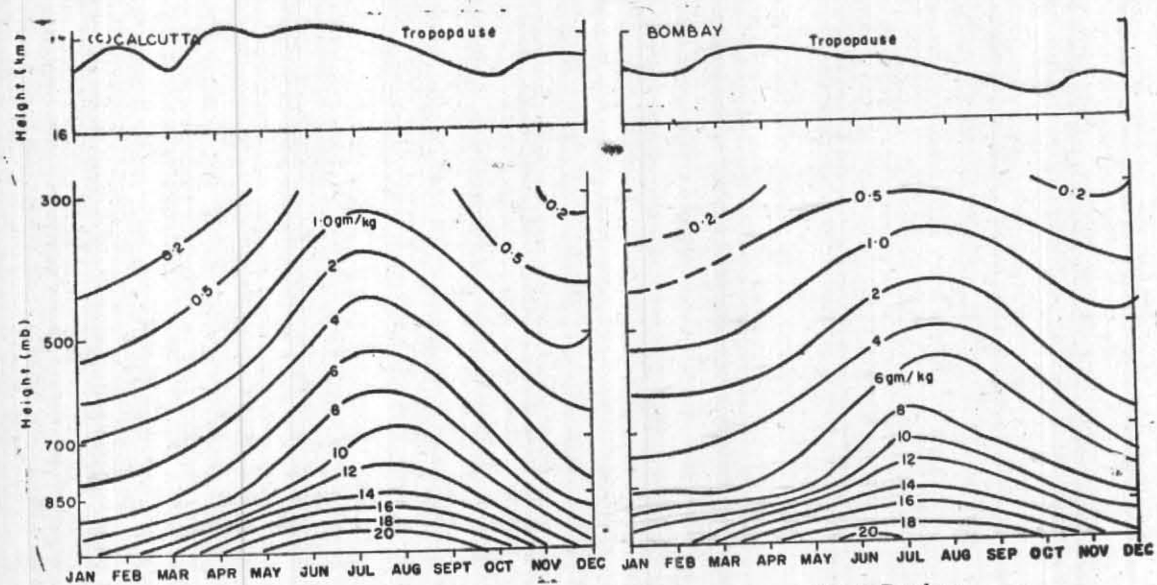


Fig. 4(c). Calcutta Fig. 5. Bombay

Mean water vapour mixing ratio and tropopause height

Lat. 19°N, neither the postulations of Godbole and Kelkar (1971) nor that of Smith (1973) appear to hold good. Figs. 6(a, b and c) give the tropopause height and mixing ratio over Madras (representing the central Peninsula) and Minicoy and Trivandrum (representing the southernmost parts of the country) respectively. Over all these three stations, the tropopause occurs at lower and lower levels with an increase in the moisture. In respect of the south Peninsula, therefore, the postulations of Smith (1963) appear to agree.

2.4. We shall now proceed further south and examine the distribution of moisture and height of tropopause over Gan*, Singapore* and Nairobi** (equatorial stations—Figs. 7a to c). Over all these stations, the tropopause occurs at the lowest level during August. We notice that over Gan and Singapore there is very little monthly variation in mixing ratio above 500 mb. Even below 500 mb, the monthly variation in the mixing ratio

*Based on data for the period 1962-70

**Based on data for the period 1956-60

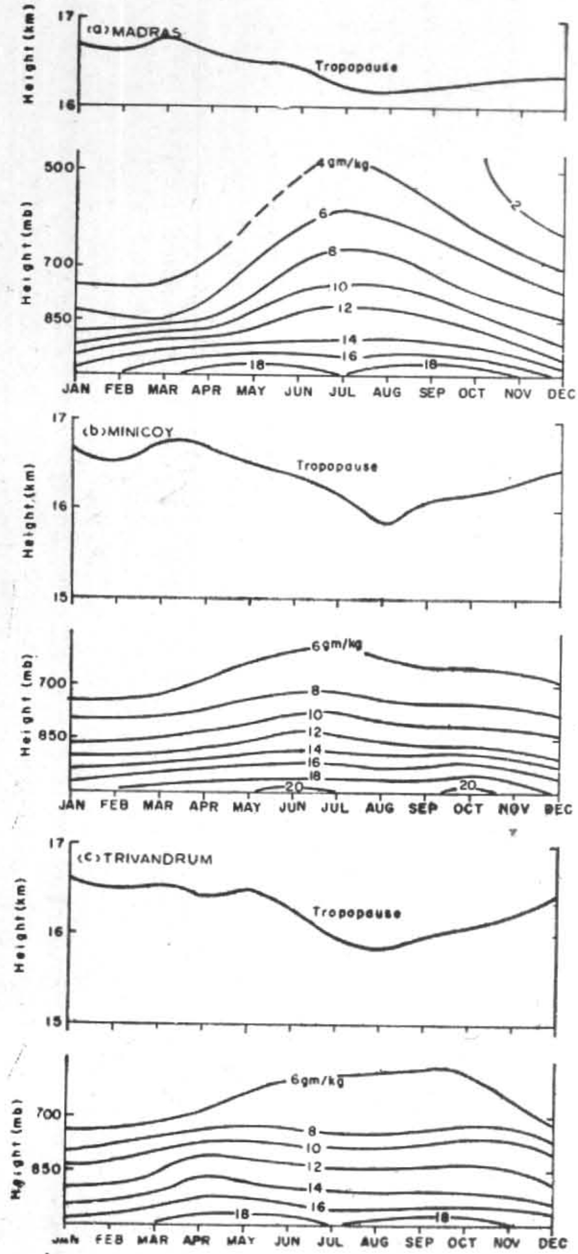


Fig. 6. Mean water vapour and mixing ratio and tropopause ht over (a) Madras, (b) Minicoy and (c) Trivandrum.

is not very significant over these stations. However, the tropopause lowering from April to August and rising from August to December is not having any phase with even the slight variation in the mixing ratio month after month. Over Nairobi, the mixing ratio lowers gradually from May to August and later increases till October in the mid and upper troposphere and we see the tropopause also lowering from May to August and then rising. We find the maximum range in the tropopause height occurs over Gan where there is very little month to month variation in the mixing ratio. Where the range in tropopause height is minimum (Nairobi), the range of mixing ratio is more than that over Gan and Singapore. We also see from Fig. 7 that the mixing ratio over Nairobi is generally lower in the middle and upper troposphere as compared to Gan and Singapore and yet the tropopause occurs over this station very much higher than over Gan and Singapore.

2.5. We have seen earlier that over Gan, the tropopause gradually lowers itself from April reaching the lowest value in August and then rising again. We have given in Table 3 the mean monthly mixing ratio of water vapour from 1000 to 300 mb from June through September in respect of each year 1962-1970 for this station. We have also shown in this table the mean tropopause height for these four months. From Table 3 we see that generally little change in mixing ratio is observed at all levels from month to month, though the tropopause reaches the lowest point in August and rises again. We would like to draw particular attention to the years 1965 and 1969. During these two years, the tropopause came down by as much as 0·66 and 0·52 km respectively from July to August. In both the years, the mixing ratio *increased* at all levels from July to August.

2.6. It is a well known fact that the moisture content decreases appreciably in the middle troposphere during break monsoon spells, even though there is not much of a change in the lower troposphere. In view of this decrease in moisture content in the middle troposphere during break monsoon spells, one should normally expect the tropopause level also to lower during such spells in view of the postulations of Godbole and Kelkar (1971) and Godbole (1973). To check up whether this was so, we chose 35 days of active monsoon and 28 days of break monsoon during July-August in respect of the three-year period 1971-1973. The years 1971–1973 were chosen for the reason that since 1971 *all* the RS stations in India (except Cochin) are using the *same* type of radiosonde instrument and dew point temperatures are available beyond the middle troposphere almost every day. The mean mixing ratio values at intervals of 50 mb upto 300 mb for each Indian radiosonde station were worked out for these spells of active and break monsoon. The mean tropopause heights during these spells in respect of each such station was also worked out. Similar information in respect of Gan pertaining to such spells *over India* during July–August for the 7-year period 1963-1969 (representing 59 days of active and 62 days of break monsoon) was also worked out.

2.7. The mean mixing ratios during these spells and the mean height of tropopause for each

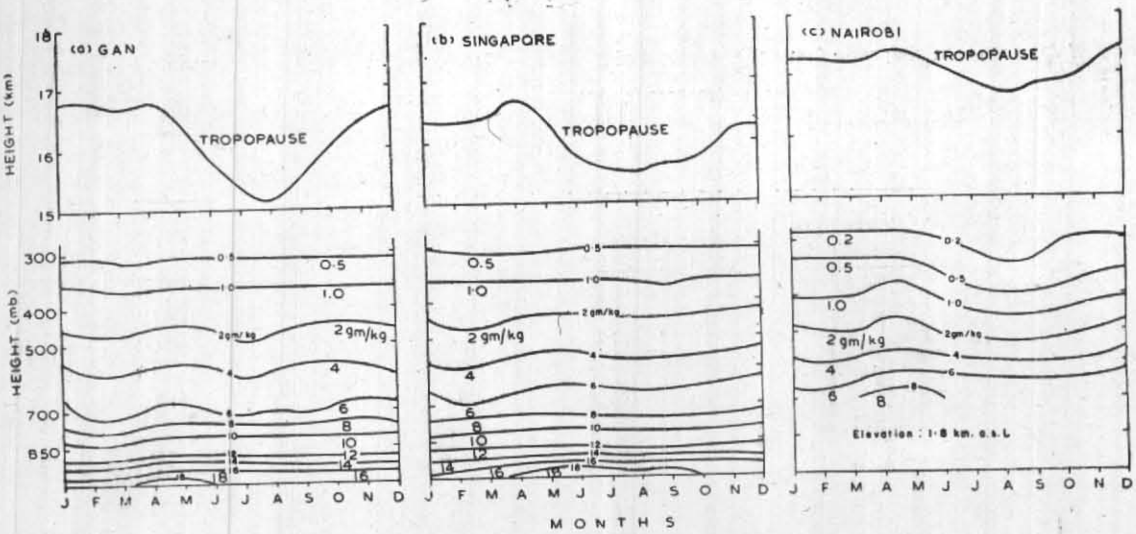


Fig. 7. Mean water vapour mixing ratio and tropopause height over (a) Gan, (b) Singapore and (c) Nairobi

TABLE 3

Monthly mean water vapour mixing ratio (gm/kg) over Gan (1962—1970)

Level (mb)	Jun	Jul	Aug	Sep	Jun	Jul	Aug	Sep	Jun	Jul	Aug	Sep
		1962				1963				1964		
300	0·41	0·45	0·47	0·51	0·43	0·37	0·36	0·40	0·42	0·43	0·41	0·45
400	1·0	1·2	1·4	1·4	1·2	1·2	1·2	1·1	1·2	1·4	1·1	1·2
500	2·3	2·0	2·6	2·7	2·1	2·3	2·4	2·4	2·2	2·4	2·1	2·1
700	5·9	5·7	6·0	6·1	6·6	4·9	5·9	6·7	4·4	5·0	5·7	5·3
850	10·2	10·9	10·3	10·5	11·0	10·9	10·3	11·2	10·3	10·0	10·3	10·0
1000	18·0	17·6	17·5	17·5	17·9	18·2	19·0	18·2	17·2	20·8	17·3	16·5
Tropopause ht (km)	16·03	15·60	15·35	15·76	16·61	15·79	15·57	16·48	15·73	15·14	15·11	15·26
		1965				1966				1967		
300	0·38	0·36	0·47	0·44	0·37	0·42	0·41	0·48	0·38	0·39	0·39	0·43
400	1·1	1·1	1·5	1·4	1·1	1·3	1·2	1·5	1·3	1·1	1·3	1·4
500	2.4	2·2	2·9	2·7	2·3	2·1	2·1	2·9	2·5	1·8	2.7	2.6
700	5·6	5·6	6·0	6·3	5·5	6·5	5·3	6·2	5·7	5·5	6·4	5·7
850	10·0	10·6	10·6	10·5	10·5	11·5	10·5	10·8	10·7	10·8	10·6	10·1
1000	16·6	16·6	16·7	16·6	17·4	17·9	17·5	17·1	18·2	18·6	17·5	17·4
Tropopause ht km)	15·71	15·93	15·27	16·15	15·96	15·65	15·19	15·21	15·43	15·05	14·91	15·02
		1968				1969				1970		
300	0·39	0·45	0·38	0·34	0·39	0·33	0·40	0·32	0·40	0·35	0·33	0·37
400	1·0	1·2	1·1	1·2	1·2	0·9	1·2	0·9	1·4	1·1	1·2	1·4
500	1·9	2·0	2·2	2·4	2·5	1·5	2·5	2·5	2·5	1·9	2·2	2·7
700	4·7	6·0	6·2	5·2	6·3	4·8	6·1	5·8	6·1	5·4	5·7	5·7
850	10·5	10·8	10·8	10·5	11·0	10·0	10·7	10·5	10·7	10·8	10·5	10·5
1000	18·4	17·7	17·3	18·2	17·7	17·2	17·5	17·4	18·6	17·7	17·7	17·9
Tropopause ht (km)	15·19	14·87	14·72	15·20	16·15	15·53	15·01	15·42	15·59	15·03	14·85	15·26

TABLE 4

Water vapour mixing ratio (gm/kg) and height of tropopause during active and break monsoon spells over India and their differences (active *minus* break monsoon spells)

Monsoon spells	Water vapour mixing ratio (gm/kg) at pressure levels (mb)														Tropopause height (km)
	950	900	850	850	750	700	650	600	550	500	450	400	350	300	
							Srinagar								
Active (A)	..	..	..	13·5	11·4	9·3	7·7	6·0	5·0	3·8	2·7	1·8	1·1	0·68	16·52
Break (B)	..	..	..	13.1	10·4	8·7	7·2	5·5	4·1	2·8	2·2	1·6	1·0	0·78	16·66
(A)—(B)	..	..	..	+0·4	+1·0	+0·6	+0·5	+0·5	+0·9	+1·0	+0·5	+0·2	+0·1	—0·10	—0·14
							New Delhi								
Active (A)	19·4	17·3	15·4	13.4	11·4	9·4	7·8	6·1	4·8	3·7	2·9	1·9	1·3	0·75	16·73
Break (B)	17·8	16·0	14·2	12·9	11·0	8·2	6·2	4·7	3·9	2·8	2·4	1·9	1·9	0·79	17·15
(A)—(B)	+1·6	+1·3	+1·2	+0·6	+0·4	+1·2	+1·6	+1·4	+0·9	+0·9	+0·5	+0·0	+0·0	—0·04	—0·42
							Jodhpur								
Active (A)	18·5	17·1	15·5	14·0	12·2	10·4	8·0	5·8	5·4	4·1	3·0	1·9	1·2	0·66	16·88
Break (B)	16·9	15·3	13·6	11·6	8·8	7·2	5·5	4·2	3·3	2·8	2·3	1·7	1·1	0·74	17·34
(A)—(B)	+1·6	+1·8	+1·9	+2·4	+3·4	+3·2	+2·5	+1·6	+2·1	+1·3	+0·7	+0·2	+0·1	—0·08	—0·46
							Lucknow								
Active (A)	19·3	16·8	15·5	12·9	11·3	9·6	7·8	6·0	4·9	3·6	2·8	1·8	1·0	0·56	16·75
Break (B)	18·5	15·8	14·2	12·5	11·2	9·3	7·0	5·4	4·3	3·5	2·5	2·0	1·1	0·65	17·16
(A)—(B)	+0·8	+1·0	+1·3	+0·4	+0·1	+0·3	+0·8	+0·6	+0·6	+0·1	+0·3	—0·2	—0·1	—0·09	—0·41
							Gauhati								
Active (A)	19·3	17·3	15·2	13·5	11·9	10·1	8·5	7·1	5·8	4·8	3·1	2·1	1·3	0·65	16·32
Break (B)	19·4	17·6	15·6	14·1	12·4	10·8	9·3	7·7	6·3	5·1	3·7	2·7	1·6	0·84	17·19
(A)—(B)	—0·1	—0·3	—0·4	—0·6	—0·5	—0·7	—0·8	—0·6	—0·5	—0·3	—0·6	—0·6	—0·3	—0·19	—0·87
							Ahmedabad								
Active (A)	17·4	15·9	14·4	12·7	10·9	9·1	7·5	6·4	5·3	4·4	3·0	2·1	1·3	0·70	16·57
Break (B)	16·0	14·0	13·0	11·3	8·2	6·5	4·7	3·7	2·8	2·3	1·9	1·3	0·8	0·43	16·96
(A)—(B)	+1·4	+1·9	+1·4	+1·4	+2·7	+2·6	+2·8	+2·7	+2·5	+2·1	+1·1	+0·8	+0·5	0·27	—0·39
							Nagpur								
Active (A)	18·5	16·4	14·7	13·1	11·7	10·2	8·5	7·1	6·0	4·7	3·3	2·2	1·3	0·58	16·45
Break (B)	16·2	14·5	13·2	11·8	10·2	8·2	6·5	5·1	4·4	3·3	2·4	1·8	1·1	0·62	—16·81
(A)—(B)	+2·3	+1·9	+1·5	+1·3	+1·5	+2·0	+2·0	+2·0	+1·6	+1·3	+0·9	+0.4	+0·2	—0·04	—0·36
							Calcutta								
Active (A)	18·4	16·2	14·7	13·1	11·5	10·0	8·5	7·3	6·1	4·9	3·6	2·1	1·3	0·67	16·44
Break (B)	19·0	16·8	14·6	13·1	11·1	9·1	7·6	6·5	5·5	4·4	3·3	2·3	1·4	0·72	16·82
(A)—(B)	—0·6	—0·6	+0·1	0·0	+0·4	+0·9	+0·9	+0·8	+0·6	+0·5	+0·3	—0·2	—0·1	—0·05	—0·38
							Bombay								
Active (A)	16·6	14·4	12·9	11·5	10·4	7·5	7·0	5·8	5·0	3·8	2·9	2·1	1·4	0·73	16·32
Break (B)	16·7	13·9	12·3	11·1	9·4	6·9	5·7	4·5	3·5	2·8	2·1	1·6	1·0	0·55	16·62
(A)—(B)	—0·1	+0·5	+0·6	+0·4	+1·0	+0·6	+1·3	+1·3	+1·5	+1·0	+0·8	+0·5	+0·4	+0·18	—0·30
							Cuttack								
Active (A)	17·9	15·4	13·1	12·1	10·2	8·7	7·4	6·4	5·2	4·2	3·0	2·1	1·3	0·75	16·24
Break (B)	16·8	14·7	13·0	11·5	9·7	7·8	6·5	5·4	4·5	3·7	2·9	2·0	1·2	0·74	16·35
(A)—(B)	+1·1	+0·7	+0·1	+0·6	+0·5	+0·9	+0·9	+1·0	+0·7	+0·5	+0·1	+0·1	+0·1	+0·01	+0·07
							Visakhapatnam								
Active (A)	17·4	14·9	13·5	12·0	10·7	9·2	7·7	6·5	5·3	4·2	3·3	2·2	1·2	0·63	16·22
Break(B)	17·3	14·6	12·9	11·4	9·8	7·7	6·7	5·7	4·4	3·3	2·6	1·7	1·2	0·65	16·48
(A)—(B)	+0·1	+0·3	+0·6	+0·6	+0·9	+1·5	+1·0	+0·8	+0·9	+0·9	+0·7	+0·5	+0·0	—0·02	—0·26

TABLE 4 (*contd*)

Monsoon spells	Water vapour mixing ratio (gm/kg) at pressure levels (mb)														Tropo-pause height (km)
	950	900	850	800	750	700	650	600	550	500	450	400	350	300	
							Bangalore								
Active (A)	..	14·9	12·6	10·7	8·8	7·0	6·0	5·1	4·2	2·8	1·6	1·0	0·7	0·43	16·43
Break (B)	..	14·1	11·7	10·4	8·8	7·0	5·5	4·2	3·3	2·3	1·7	1·1	0·7	0·35	16·40
(A)—(B)	..	+0·8	+0·9	+0·3	0·0	0·0	+0·5	+0·9	+0·9	+0·5	—0·1	—0·1	—0·0	0·08	+0·03
							Madras								
Active (A)	15·2	13·0	11·9	10·8	9·6	7·9	6·6	5·6	4·2	2·7	1·7	1·3	0·9	0·53	16·19
Break (B)	14·9	12·3	12·0	11·1	9·5	7·7	6·0	4·4	3·5	2·6	1·8	1·3	0·8	0·44	16·36
(A)—(B)	+0·3	+0·7	—0·1	—0·3	+0·1	+0·2	+0·6	+1·2	+0·7	+0·1	—0·1	0·0	0·1	+0·09	—0·17
							Minicoy								
Active (A)	16·5	13·2	11·1	9·0	7·1	5·5	4·6	3·6	3·2	2·4	1·7	1·2	0·8	0·43	16·01
Break (B)	17·1	13·9	10·8	8·4	6·4	5·0	4·3	3·4	3·1	2·2	1·6	1·2	0·7	0·34	16·04
(A)—(B)	—0·6	—0·7	+0·3	+0·6	+0·7	+0·5	+0·3	+0·2	+0·1	+0·2	+0·1	0·0	+0·1	+0·09	—0·03
							Trivandrum								
Active (A)	14·9	12·6	11·1	9·4	7·6	5·8	4·6	4·2	3·3	2·3	1·6	1·1	0·7	0·37	15·83
Break (B)	14·8	12·2	10·4	9·0	6·7	5·6	4·9	4·0	3·0	2·2	1·5	0·8	0·5	0·26	15·99
(A—(B)	+0·1	+0·4	+0·7	+0·4	+0·9	+0·2	—0·3	+0·2	+0·3	+0·1	+0·1	+0·3	+0·2	+0·11	—0·16
							Port Blair								
Active (A)	17·3	14·8	12·3	10·3	8·3	6·9	5·2	4·8	4·2	3·6	2·9	2·1	1·3	0·61	15·80
Break (B)	17·6	15·4	12·8	10·4	8·5	7·0	5·5	4·5	3·7	2·9	2·3	1.6	0·9	0·53	16·27
(A)—(B)	—0·3	—0·6	—0·5	—0·1	—0·2	—0·1	—0·3	+0·3	+0·5	+0·7	+0·6	+0·5	+0·4	+0·08	—0·47
							Gan								
Active (A)	15·3	12·8	10·6	8·4	6·6	5·3	4·1	3·2	2·7	2·3	1·7	1·2	0·7	0·39	15·30
Break (B)	15·2	12·7	11·0	9·1	7·2	5·9	4·9	3·8	3·6	3·0	2·1	1·4	0·9	0·45	14·96
(A)—(B)	+0·1	+0·1	—0·4	—0·7	—0·6	—0·6	—0·8	—0·6	—0·9	—0·7	—0·4	—0·2	—0·2	—0·06	—0·34

station along with the differences (active *minus* break) are given in Table 4.

2.8. From Table 4 we see that there is a general decrease in moisture content over the country above 800-750 mb during break spells. The exceptions are : Gauhati where the moisture content is higher at and above 850 mb during break spells (this should be expected, as the rainfall increases along the foot of the Himalayas during break monsoon spells) ; Port Blair, Minicoy and Trivandrum where there is not much difference in moisture between the two spells and Gan where the moisture is higher during break spells at and above 850 mb. We notice, however, that the mean tropopause level is *higher* at almost all Indian stations during breaks. The tropopause level has gone up during breaks with:

(*a*) an *increase* in moisture in the levels 850 mb and above (as at Gauhati),

(*b*) a *decrease* in moisture (as in the case of Srinagar, New Delhi, Jodhpur, Lucknow, Ahmedabad, Nagpur, Clacutta, Bombay, Visakhapatnam and Madras) and

(*c*) *little change* in moisture (as in the case of Port Blair, Minicoy and Trivandrum).

The tropopause level has *remained more or less same* with a *decrease* in the moisture (as in the case of Cuttack and Bangalore). It has *lowered* over Gan with an *increase* in moisture.

2.9. From the foregoing, it is seen that even within the monsoon season, when the moisture distribution undergoes striking changes in the middle and upper troposphere during breaks, the behaviour of the tropopause appears to be independent of the moisture content below.

3. Conclusions

3.1. From all the evidences adduced above, only one picture emerges, *viz.*, the behaviour of the tropopause does not appear to have any direct relationship with the increase or decresase of moisture in the lower, middle or upper troposphere, either latitudinally during a particular month, or during different months over the same station, or during spells of active or break monsoon over the country. It is, therefore, our submission that the postulations of Godbole (1973) and Godbole and Kelkar (1971) on the basis of computations made on an individual observational point during July 1964-65, do not appear to be borne out by observed facts.

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