

A summary of the debriefing reports from 'Comets'

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1. Introduction

In May 1952, the B.O.A.C. introduced on regular schedule 'COMET' Jet Aircraft operating at about 40,000 feet on London-Singapore and London-Colombo routes passing also through Karachi, New Delhi, Calcutta, Rangoon and Karachi, Bombay, Colombo respectively. Since then debriefing reports are being received from aircraft Commanders regarding meteorological conditions experienced by them during their flights on portion of routes passing over India and the neighbouring regions. Before this period very little information was available regarding weather and cloud development above 15,000 ft over India and neighbourhood in view of absence of adequate meteorological reconnaissance flights at high altitudes and the commercial flying on national routes being generally confined to a cruising height below 15,000 ft. Even, of this data reports relating particularly to heights of high clouds and heights of tops of large cumulus and cumulonimbus clouds were observations based on estimation and not on direct measurement. Also, hitherto, our knowledge regarding upper winds and temperatures are based on indirect measurements of the same through balloons and instruments let off from the ground. As the debriefing reports of 'COMET' flights contain actual observations regarding clouds, wind and weather upto about 40,000 ft or a little above, they were examined with a view to find out how far the information contained therein compare with our knowledge regarding these elements as already

available from other sources. It is found that our ideas particularly regarding heights of tops of large cumulus and cumulonimbus clouds require modification as these clouds are found to develop to much greater heights than was presumed earlier. A brief synopsis of the more interesting features arising from a study of the debriefing reports collected during the period May 1952 to December 1953 is given below.

2. Clouds

Tables 1(a) and 1(b) show frequencies of heights of tops of cumuliform clouds and heights of bases and tops of high and medium clouds over Colombo-Bombay route and Delhi-Calcutta route respectively.

(a) *Over Colombo-Bombay route*—It is seen that during the period December-February, tops of cumulus clouds were generally below 8000 ft. On one occasion it reached 20,000 ft. During the rest of the year tops of cumulus clouds generally extended between 8000-20,000 ft. During the monsoon and post monsoon months (June-November) on some occasions they extended to greater heights and went even above 40,000 ft. The highest top reported was 42,000 ft for the period June-September and 45,000 ft for the period October-November. It is, therefore, evident that large cumulus cloud is not always wholly a warm cloud.

It is interesting to note that there were only very few reports of cumulonimbus clouds with tops below 25,000 ft. Their tops generally extended between 33,000-45,000 ft in all the seasons of the year. On a few

occasions they shot up even to greater heights. The highest value reported was 51,000 ft near Bombay on 2 October 1952. In this connection it may be mentioned that cumulonimbus clouds reaching even 54,600 ft over Sumatra has been reported by Frost (1952).

The bases of medium clouds were generally between 8000–15,000 ft during June–November. On some occasions they were between 18,000–22,000 ft. Their tops were generally between 18,000–25,000 ft. The highest top reported was 30,000 ft. Reports for the period December–May were so few that no definite conclusions could be drawn.

High clouds generally formed between 30,000 and 40,000 ft in all the seasons of the year. Sometimes they occurred at 40,000–50,000 ft.

(b) *Over Delhi-Calcutta route*—Reports regarding heights of tops of cumuliform clouds for the period October–March are too meagre. It is seen from Table 1(b) that during the summer and monsoon periods (April–September) tops of cumulus clouds generally extended between 12,000 and 20,000 ft. On a few occasions cumulus tops reached 25,000 ft. Tops of cumulonimbus clouds were generally from 28,000 to 40,000 ft. There were only very few instances of their tops being below 25,000 ft. On several occasions their tops extended well above 40,000 ft and sometimes touched even 50,000 ft. The bases and tops of medium clouds mainly varied between 8000–10,000 ft and 20,000–25,000 ft respectively during the period March–September. The highest value for the top was 35,000 ft. Reports for other months were very few.

High clouds were generally found between 28,000 and 40,000 ft. On a few occasions, particularly during the period December–April high clouds were reported to form between 20,000 and 25,000 ft. It appears that in general, over northern and north-eastern parts of India high clouds occur at levels lower than over the Peninsula.

3. Upper winds and temperatures

The temperatures and winds reported by the 'COMET' and their variations at different levels are in general agreement with the known facts about these elements in and near the Indian region. It may be pointed out that during winter (December–February) the mean wind (260°/90 kts) at the cruising level over Delhi-Calcutta route indicated by 'COMET' reports agree closely with the value indicated by Koteswaram and others (1953) as computed from radiosonde data and is considerably greater than the value presented by Venkiteswaran (1950). As pointed out by Koteswaram, the latter's data based on pilot balloon flights could not have included occasions of high winds when ascents were not possible.

4. Icing

There was only one report regarding icing. This was on 8 October 1952 during descent near Bombay at about 1530 IST while flying through *As* cloud when a deposit of clear ice was reported. Cloud amount was given as 6 octas, base 20,000 ft (temperature — 4°C) and top reaching 26,000 ft.

5. Turbulence

Tables 2(a) and 2(b) contain particulars regarding turbulence reported during the period May 1952 to December 1953. It is seen that over Colombo–Bombay route, except very few occasions of clear air turbulence, turbulence was generally associated with clouds. The chances of turbulence being encountered seem to be greater while flying through or close to convective clouds, *Cu*, *Cb*, *Ac* and *Cc*, there being only very few reports—mainly of light turbulence, in *Cs* and *Ci*. Moderate and heavy turbulence were chiefly associated with *Cb* and well developed large *Cu*, indicating much instability and vigorous drafts. There was only one report of moderate clear air turbulence. It is also interesting to note that *Ac* and *Cc* clouds associated with turbulence were also 10,000–12,000 ft thick.

Over Calcutta–Delhi route during the summer and monsoon months turbulence

appears to be mainly associated with *Cb* clouds. However, clear air turbulence was more frequent during the period November-February, generally during cruise at about 35,000 ft. It may be mentioned that Choudhury (1950), Krishna Rao (1952) and Koteswaram and others (1953) have shown that 'jet streams' occur in this region during winter. It appears probable that the greater frequency for clear air turbulence at about the cruising level over this route during

November-February may be due partly at least to the prevalence of jet streams over this region during the above period. An occasion of occurrence of jet stream over this area when severe turbulence was also reported is being studied separately.

6. Acknowledgement

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TABLE 1 (a)

Colombo—Bombay route

Frequencies of heights of tops of cumuliform clouds and heights of base and tops of medium and high clouds

Height (thousands of feet)	Dec- Feb	Mar- May	Jun- Sep	Oct- Nov
Frequencies of heights of tops of cumuliform clouds				
	<i>Cumulus clouds</i>			
04—08	5		7	6
8.1—10.0		1	6	5
10.1—12.5	1	1	7	6
12.6—15.0			4	7
15.1—17.5		1	1	5
17.6—20.0	1	1	9	8
20.1—22.5			4	
22.6—25.0		1	1	2
25.1—27.5			1	
27.6—30.0			3	2
30.1—32.5			2	
32.6—35.0			2	
35.1—37.5				1
37.6—40.0			2	1
40.1—42.5			1	1
42.6—45.0				2
45.1—47.5				
47.6—50.0				
>50				
Highest top	20	25	42	45
Total number of observations	7(A4, C2, D1)	5(A4, C1)	50(A9, C24, D17)	46(A31, C14, D11)
<i>Cumulonimbus clouds</i>				
04—08				
8.1—10.0				
10.1—12.5				
12.6—15.0				
15.1—17.5	1			
17.6—20.0				
20.1—22.5		1		
22.6—25.0				
25.1—27.5			2	2
27.6—30.0			2	2
30.1—32.5			1	1
32.6—35.0			2	2
35.1—37.5			6	4
37.6—40.0	1		4	7
40.1—42.5	1	1	3	5
42.6—45.0	1	3	2	10
45.1—47.5				
47.6—50.0		2		3
>50				1
Highest top	45	50	45	51
Total number of observations	4(A2, C2)	7(A1, C5, D1)	22(A4, C18)	37(A13, C18, D6)

TABLE 1(a)—contd

Height (thousands of feet)	Dec- Feb	Mar- May	Jun- Sep	Oct- Nov
Frequencies of heights of base of medium clouds				
04—08			2	1
8.1—10.0			8	1
10.1—12.5			4	
12.6—15.0			1	1
15.1—17.5			2	
17.6—20.0	3	1	8	2
20.1—22.5			2	
22.6—25.0			1	1
25.1—27.5				
27.6—30.0				
30.1—32.5				
32.6—35.0				
35.1—37.5				
37.6—40.0				
40.1—42.5				
42.6—45.0				
45.1—47.5				
47.6—50.0				
>50				
Highest top				
Total number of observations	3(A1, C1, D1)	1(A1)	28(A10, C11, D7)	6(A3, C1, D2)
<i>Frequencies of heights of tops of medium clouds</i>				
04—08				
8.1—10.0				1
10.1—12.5				2
12.6—15.0				3
15.1—17.5				1
17.6—20.0				3
20.1—22.5				2
22.6—25.0	1			5
25.1—27.5				1
27.6—30.0	1			2
30.1—32.5				
32.6—35.0				
35.1—37.5				
37.6—40.0				
40.1—42.5				
42.6—45.0				
45.1—47.5				
47.6—50.0				
>50				
Highest top	29		30	30
Total number of observations	2(C1, D1)		20(A6, C8, D6)	7(A3, C3, D1)

A—Ascent Colombo—200 nautical miles approx. ; C—Cruise; Central 450 nautical miles approx.

D—Descent—200 nautical miles (approx)—Bombay

NOTE—Heights refer to pressure altitudes. It is assumed that the cross-section is reversible

TABLE 1(a)—*contd*

TABLE 1 (b)

Delhi—Calcutta route

Frequencies of heights of tops of cumuliform clouds and heights of base and tops of medium and high clouds

Height (thousands of feet)	Dec-Feb	Mar-May	Jun-Sep	Oct-Nov
<i>Frequencies of heights of base of high clouds</i>				
04—08				
8.1—10.0				
10.1—12.5				
12.6—15.0				
15.1—17.5				
17.6—20.0				
20.1—22.5				
22.6—25.0			2	
25.1—27.5				
27.6—30.0	1		7	1
30.1—32.5			5	1
32.6—35.0	5	1	11	6
35.1—37.5	1	1		
37.6—40.0	3	1	9	4
40.1—42.5			2	
42.6—45.0			1	2
45.1—47.5				
47.6—50.0	1		1	
>50				
Highest top				
Total number of observations	11(A4, C4, D3)	3(A2, C1)	38(A9, C22, D7)	14(A6, C7, D1)

Height (thousands of feet)	Dec-Feb	Mar-May	Jun-Sep	Oct-Nov
<i>Frequencies of heights of tops of cumuliform clouds</i>				
<i>Cumulus clouds</i>				
04—08				
8.1—10.0		1		
10.1—12.5		1		
12.6—15.0				5
15.1—17.5		1		1
17.6—20.0		1		6
20.1—22.5	1			
22.6—25.0		2		3
25.1—27.5				
27.6—30.0				
30.1—32.5				
32.6—35.0				
35.1—37.5				
37.6—40.0				
40.1—42.5				
42.6—45.0				
45.1—47.5				
47.6—50.0				
>50				
Highest top	22	25	25	
Total number of observations	1 (D1)	7(A1, D6)	15(A4, C3, D8)	

Height (thousands of feet)	Dec-Feb	Mar-May	Jun-Sep	Oct-Nov
<i>Frequencies of heights of tops of high clouds</i>				
04—08				
8.1—10.0				
10.1—12.5				
12.6—15.0				
15.1—17.5				
17.6—20.0				
20.1—22.5				
22.6—25.0				
25.1—27.5				
27.6—30.0			1	
30.1—32.5				
32.6—35.0			4	
35.1—37.5	2	1	2	1
37.6—40.0	5	1	14	6
40.1—42.5			2	3
42.6—45.0			2	3
45.1—47.5			1	
47.6—50.0			1	1
>50				
Highest top	40	40	48	50
Total number of observations	7(A4, C2, D1)	2(A2, D5)	27(A2, C20, D5)	14(A7, C7)

Height (thousands of feet)	Dec-Feb	Mar-May	Jun-Sep	Oct-Nov
<i>Cumulonimbus clouds</i>				
04—08				
8.1—10.0				
10.1—12.5				
12.6—15.0				
15.1—17.5				
17.6—20.0				
20.1—22.5		1		
22.6—25.0				2
25.1—27.5	1			
27.6—30.0	1	1		8
30.1—32.5	1			1
32.6—35.0	1			4
35.1—37.5		1		2
37.6—40.0		2		17
40.1—42.5				2
42.6—45.0				11
45.1—47.5				
47.6—50.0		1		6
>50				
Highest top	35	48	50	30
Total number of observations	4(A1, C2, D1)	6(C1, D5)	52(A13, C21, D18)	1 (D1)

A—Ascent; Colombo—200 nautical miles approx.
 C—Cruise; Central 450 nautical miles approx.
 D—Descent—200 nautical miles (approx.)—Bombay

A—Ascent *i.e.* approx. first 170 nautical miles of route
 C—Cruise *i.e.* Central 370 nautical miles approx.
 D—Descent *i.e.* approx. last 170 nautical miles of route

NOTE—Heights refer to pressure altitudes. It is assumed that the cross-section is reversible

TABLE 1(b)—*contd*

Height (thousands of feet)	Dec- Feb	Mar- May	Jun- Sep	Oct- Nov
<i>Frequencies of heights of base of medium clouds</i>				
04—08				
8.1—10.0	1	1	4	
10.1—12.5	1	5		
12.6—15.0	1	2	3	
15.1—17.5		1	1	
17.6—20.0		2	1	
20.1—22.5			1	
22.6—25.0				
25.1—27.5				
27.6—30.0				
30.1—32.5				
32.6—35.0				
35.1—37.5				
37.6—40.0				
40.1—42.5				
42.6—45.0				
45.1—47.5				
47.6—50.0				
>50				
Highest top				
Total number of observations	3(C1, D2)	11(A3, C4, D4)	10(A1, C3, D6)	

Frequencies of heights of tops of medium clouds

04—08				
8.1—10.0				
10.1—12.5	1			
12.6—15.0				
15.1—17.5	1			
17.6—20.0			1	1
20.1—22.5			1	
22.6—25.0		2		
25.1—27.5				
27.6—30.0		2		
30.1—32.5				
32.6—35.0			1	
35.1—37.5				
37.6—40.0				
40.1—42.5				
42.6—45.0				
45.1—47.5				
47.6—50.0				
>50				
Highest top	16	28	35	16
Total number of observations	2(C1, D1)	4(A1, C2, D1)	3(A1, C2)	1(C1)

TABLE 1(b)—*contd*

Height (thousands of feet)	Dec- Feb	Mar- May	Jun- Sep	Oct- Nov
<i>Frequencies of heights of base of high clouds</i>				
04—08				
8.1—10.0				
10.1—12.5				
12.6—15.0				
15.1—17.5				
17.6—20.0	3	2		
20.1—22.5		1	1	
22.6—25.0		3	1	
25.1—27.5	1			
27.6—30.0	2	4	3	
30.1—32.5				
32.6—35.0	4	3		
35.1—37.5				
37.6—40.0				1
40.1—42.5				
42.6—45.0				
45.1—47.5				
47.6—50.0				
>50				
Highest top				
Total number of observations	10(A1, C6, D3)	13(C7, D6)	6(A1, C3, D2)	

Frequencies of heights of tops of high clouds

04—08			
8.1—10.0			
10.1—12.5			
12.6—15.0			
15.1—17.5			
17.6—20.0			
20.1—22.5	1		
22.6—25.0			
25.1—27.5			
27.6—30.0			
30.1—32.5			
32.6—35.0	2		2
35.1—37.5		1	1
37.6—40.0	1	3	
40.1—42.5			
42.6—45.0			
45.1—47.5			
47.6—50.0			
>50			
Highest top	40	40	36
Total number of observations	4(C2, D2)	4(A1, C2,D1)	3(A1, D2)

A—Ascent *i.e.* approx. first 170 nautical miles of routeC—Cruise *i.e.* central 370 nautical miles approx.D—Descent *i.e.* approx. last 170 nautical miles of route

NOTE—Heights refer to pressure altitudes. It is assumed that the cross-section is reversible

TABLE 2 (a)
Colombo—Bombay route

Date	Approx. time (IST)	Particulars of flight	Kind of turbulence	Clouds and weather	Remarks, if any, by the crew
29- 6-52	1500	Cruise	No specification	<i>Cs</i> and <i>Cb</i> tops	Felt in clouds
30- 6-52	1130	Cruise	Moderate	Cloudy. <i>Cb</i> tops at 42,000 ft	Felt near 13°N
13- 8-52	1500	Cruise	Slight	<i>Cu</i>	Felt in clouds, probably <i>Cu</i> tops
24- 8-52	0930	Cruise	Slight	<i>Ci</i> 8/8 base 30,000 ft top 33,000 ft	
10- 9-52	1400	Cruise	Slight	<i>Cs</i> becoming <i>Cc</i> base 28,000 ft top 40,000 ft	
10- 9-52	1500	Cruise	Slight	<i>Cc</i> base 32,000 ft top 42,000 ft	Felt at 15°N
1-10-52	1500	Descent	Heavy	Thundershowers <i>Cb</i> tops reaching 48/51,000 ft	Felt all the way from 14°N to Bombay
8-10-52	1400	Ascent	Moderate	Rain, <i>Cu</i> 5-6/8 tops 25,000 ft <i>As</i> 25/30,000 ft <i>Ci</i> 40/43,000 ft	
8-10-52	1500	Cruise	Moderate	<i>Cu</i> 4-6/8 locally 8/8 tops 35/42,000 ft	At Lat. 12-17°N when flying through clouds without a gap
22-10-52	1330	Cruise	Slight	<i>Ci</i> at 40,000 ft	In <i>Ci</i> at 39,100 ft about 60 miles north of Coimbatore
17-12-52	1230	Ascent	Moderate continuous	<i>Cs</i> base 35,000 ft top 38,000 ft	Felt below clouds above 26,000 ft, from Colombo to Lat. 10°N
11- 2-53	1400	Descent	Moderate	No clouds	Felt in clear air between 32/40,000 ft, Lat 16° and 17°N
24- 2-53	..	Cruise	Slight intermittent	<i>Cc</i> base 30,000 ft	
10- 4-53	1430	Ascent	Light	<i>Cb</i> top 22,000 ft <i>Ac</i> base 15,000 ft top 25,000 ft	Felt at 25,000 ft
22- 5-53	1500	Cruise	Moderate	<i>Cb</i> base 2000 ft top 50,000 ft	
2- 7-53	1030	Cruise	Moderate	<i>Cu</i> top 22,000 ft <i>As</i> top 20,000 ft sky overcast	
3- 7-53	1500	Cruise	Moderate	Overcast with <i>As</i> base 20,000 ft <i>Cu</i> tops 25,000 ft, high clouds with tops at 38,000 ft	Felt in first half of cruise
3- 7-53	1620	Descent	Moderate to severe	Layers of high and medium clouds below 30,000 ft, large <i>Cu</i> with tops extending to 22,000 ft	Felt over Ghats east of Bombay
8- 7-53	1500	Cruise	No specification	No clouds	Experienced clear air turbulence in second half cruise at 36/38,000 ft

TABLE 2 (a)—contd

Date	Approx. time (IST)	Particulars of flight	Kind of turbulence	Clouds and weather	Remarks, if any, by the crew
17- 8-53	1500	Cruise	Slight occasional	No clouds	Experienced in clear air
1-10-53	1520	Cruise	Light	<i>Cb</i> tops at 36/42,000 ft, locally 3-5/8 <i>Cb</i> tops at 45,000 ft, occasional hail and lightning	
30-10-53	1420	Ascent	Mild	<i>Cu</i>	Some mild turbulence in <i>Cu</i>
17-12-53	1445	Descent	Slight	No clouds	Felt in clear air

TABLE 2 (b)
Delhi—Calcutta route

Date	Approx. time (IST)	Particulars of flight	Kind of turbulence	Clouds and weather	Remarks, if any, by the crew
28-12-52	1645	Cruise	Severe	No clouds	Experienced for about 25 minutes during first half of cruise at 37,000 ft when wind was 246°/150 knots
4- 1-53	1750	Descent	Slight	Clouds not reported	Felt between 15,000 and 30,000 ft
30- 1-53	..	Cruise	Light intermittent	Nil	Felt in clear air for about 10 minutes. Winds 265°/90 knots to 269°/145 knots
1- 3-53	2100	Cruise	Light intermittent	Fine	Felt clear air turbulence between 250 and 450 miles from Palam (Delhi)
12- 3-53	1730	Ascent	Moderate	Cloudy 3/8 <i>Cb</i> , base 4000 ft, top 38,000 ft. 4/8 <i>Ac</i> at 25,000 ft	
7- 6-53	1630	Cruise	Heavy	Nil	Considerable heavy clear air turbulence after Allahabad
14- 6-53	1530	Cruise	Moderate	7/8 <i>Ci</i> , with occasional <i>Cb</i> , base 5000 ft, tops 36,000 ft	Experienced between Allahabad and Kanpur
26- 6-53	..	Ascent	Light occasional	8/8 <i>As</i> at 9000 ft overcast with occasional rain at 12,000 ft and 30,000 ft	
1- 9-53	1515	Cruise	Light	<i>Cb</i> tops extending upto 50,000 ft	Felt in <i>Cb</i> cloud
4-11-53	1400	Descent	Slight continuous	Nil	Continuous slight clear air turbulence

NOTE—Heights are expressed in pressure altitude