

Some characteristics of *Cb* clouds over the Bay of Bengal

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ABSTRACT. All available post-flight reports provided by aircrews of civil jet aircraft during the last sixteen years were scrutinised. Data regarding *Cb* clouds over the Bay were extracted and analysed. The mean heights of *Cb* tops over the Bay and their seasonal and latitudinal variations have been studied. Some other characteristics, like amounts of *Cb* clouds, turbulence and icing encountered in the vicinity of *Cb* clouds have been briefly discussed.

1. Introduction

Extensive data regarding *Cb* clouds and thunderstorms have been gathered through research projects, radar studies and reconnaissance flights in the USA and Europe. However, till recently very little data were available in respect of *Cb* clouds in a tropical country like India. Rao (1955) analysed BOAC Comet debriefing reports, totalling 187, for flights across India in 1952 and 1953. Kulshrestha (1962) made a radar study of *Cb* heights in northern India. Deshpande (1964 and 1970) carried out a detailed study of *Cb* heights based on debriefing/post flight reports of civil jet aircraft and IAF Met. reconnaissance flights. All these studies related mainly to land areas. As part of the International Indian Ocean Expedition (IIOE) in 1963-64, special efforts were made to estimate heights of *Cb* tops over the Indian Ocean through time-lapse movies and still photographs taken from well equipped research aircraft. Though valuable data about *Cb* clouds were obtained over the Arabian Sea, only a few flights were made over the Bay of Bengal (Bunker 1968).

All available post flights reports and debriefing reports relating to the Bay of Bengal during 1958-1973 were scrutinised and data relating to *Cb* clouds extracted and analysed. For greater accuracy, the analysis was confined to reports from jet aircraft whose operational altitude was 30,000 ft or higher. The present analysis is based on a total 735 reports of *Cb* clouds.

2. Analysis of data

2.1. Height frequencies

The reporting jet aircraft generally flew at cruising levels between 33,000 and 40,000 ft

(indicated). In majority of the cases, flight levels were within 5000-7000 ft of reported tops of *Cb* clouds. Hence height estimates of *Cb* tops by experienced aircrews in relation to their flight level may be regarded as fairly accurate. The available reports of *Cb* heights were tabulated for each 5000 ft height level between 20,000 ft and 55,000 ft. Table 1 shows the monthwise frequency of height levels of *Cb* tops over the Bay of Bengal as also for the year.

2.2. Seasonal variation

The variations in the heights of *Cb* tops for the four seasons, viz., the winter (December to February), the pre-monsoon (March to May), the southwest monsoon (June to September) and the post monsoon (October and November) are shown in Table 2.

2.3. Regional variation

To assess whether there is any systematic variation in the heights of *Cb* tops with latitude, the Bay of Bengal was divided into three broad regions, the north Bay (north of 18°N), the central Bay (13°N-18°N) and the south Bay (south of 13°N). *Cb* heights were tabulated separately for these three regions and percentage frequencies of heights of *Cb* tops were worked out, regionwise as well as seasonwise. These are summarised in Table 3.

2.4. Analysis of height data

Salient features brought out by Tables 1 to 3 are indicated below.

(a) The observed heights of *Cb* tops over Bay of Bengal cover a wide range from 23,000 to 52,000 ft,

TABLE 1
Frequencies of heights of Cb tops over the Bay of Bengal (1958-1973)

Ht. levels (thousands of ft)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Annual% frequencies
20-24.9									3	2			5	0.7
25-29.9		1	1	3	2	2	4	2	1	6	1		23	3
30-34.9	1	3	8	6	17	8	8	10	14	15	8	13	111	15
35-39.9	5	1	8	19	48	46	34	38	34	33	28	10	304	41.5
40-44.9	4	4	3	16	31	38	44	27	27	23	9	8	234	32
45-49.9	1				9	13	11	5	5	4	1		49	6.6
50-54.9	1	1			1	2			1	3			9	1.2
Total	12	10	20	44	108	109	101	82	85	86	47	31	735	100
Mean ht. (1000 ft)	40.8	38.5	35.8	37.9	38.9	40.2	40.0	38.9	38.9	37.9	37.6	36.7		

Total number of reports 735, Mean ht. of tops 38,800 ft, Highest top reported 52,000 ft and lowest top reported 23,000 ft

However, over 70 per cent of the reports (538 out of 735) are in the range 35,000 to 44,900 ft. The mean height of Cb tops is 38,800 ft.

(b) For the year as a whole, the height level 35,000 to 39,900 ft has the maximum number of reports, *i.e.*, 304 (41 per cent). The next level 40,000 to 44,900 ft accounts for 234 reports (32 per cent). The former also maintained a higher number of reports for January and for April to November except in July, when the number of reports for the latter level showed an increase.

(c) Total number of reports for Cb tops lower than 30,000 ft is only 28, *i.e.*, less than 4 per cent. On the other hand, on 58 occasions (nearly 8 per cent), Cb tops towered to 45,000 ft or higher. Out of these, in 9 cases Cb tops registered a height of 50,000 to 52,000 ft.

(d) The highest top of Cb clouds reported over the Bay of Bengal during the period 1958 to 1973 was 52,000 ft on a flight from Bangkok to Bombay at 36,000 ft, an Air India Captain reported a Cb towering to 52,000 ft near 16°N, 86°E at 1630 GMT on the 22 October 1962.

(e) There is a seasonal variation in the frequency and development of Cb clouds over the Bay. The maximum number of Cb reports (377 out of 735) relates to the southwest monsoon season (June to September). The percentage of Cb tops reaching 40,000 ft or higher in this season is over 45 per cent as compared to 34 per cent in the pre-monsoon and 30 per cent in the post monsoon season. The corresponding percentage for the winter season based on 53 reports is 36 per cent. Pronounced development of Cb clouds over the Bay during the southwest monsoon can be attributed to the development and movement of a large number of depressions/storms.

TABLE 2

Seasonal variation of ht. of Cb tops — % frequencies

Ht. level in thousands of ft	Percentage frequencies			
	Winter (Dec-Feb)	Pre-monsoon (Mar-May)	SW monsoon (Jun-Sep)	Post monsoon (Oct-Nov)
Below 30	2	3.5	3	7
30-34.9	32	18	10.5	17
35-39.9	30	44	41	46
40-44.9	30	29	36	24
45-49.9	2	5	9	4
50-54.9	4	0.6	0.5	2
Total No. of reports	53	172	377	133
Mean height (ft)	38,000	38,300	39,400	37,800

(f) The mean height of Cb tops is 39,400 ft in the SW monsoon season, 38,300 ft in the pre-monsoon months and 38,000 ft and 37,800 ft in the winter and post monsoon seasons respectively. It is significant that though in the latter two seasons the mean heights of Cb tops is lowest, on occasions Cb tops extend to 50,000 ft and beyond.

(g) Over the Bay of Bengal, Cb tops are on an average higher over the north Bay during the southwest monsoon and post monsoon seasons and over the south Bay during the winter months. The frequency of Cb tops reaching 40,000 ft and higher is 53 per cent over the north Bay, as compared to 38 and 43 per cent over the central and south Bay during the southwest monsoon season. The corresponding frequencies for the winter are

TABLE 3
Regional variation of percentage frequencies of heights of *Cb* tops over the Bay of Bengal

Ht. in thousands of ft	Percentage frequencies														
	Winter (Dec-Feb)			Per-monsoon (May-May)			SW monsoon (Jun-Sep)			Post monsoon (Oct-Nov)			Annual		
	N	C	S	N	C	S	N	C	S	N	C	S	N	C	S
Below 30			2.5	5	5	1.5	4	2.5	3	7.5	9	5	4.5	4	3
30-34.9	50	40	28	14	17	22	10.5	7.5	14.5	23	15	16.5	13	12.5	19
35-39.9	50	40	26	46.5	52.5	36	32	52	39	27	46	54	35.5	50.5	40
40-44.9		20	36	26	21.5	36	37	30	41	27	26	21.5	33	27	34.5
45-49.9			2.5	8.5	2	4	15.5	6	2	11.5	4	3	13	4	3
50-54.9			5		2		0.6	1.7		4			0.8	2	0.7
No. of obsns.	4	10	39	58	42	72	161	119	97	26	46	61	249	217	269
Mean ht. of tops (in 1000 ft)	35.0	36.5	38.6	38.4	37.8	38.5	40.0	39.2	38.7	38.7	37.6	37.4	39.4	38.5	38.4

N--North of 18°N, C--13° to 18°N and S--South of 13°N

TABLE 4
Frequency of *Cb* amounts in Octas

No. of obsns. in	Dec-Feb			Mar-May			Jun-Sep			Oct-Nov			Annual		
	Scattered (1-3)	Broken (4-6)	Overcast (7-8)	Scattered (1-3)	Broken (4-6)	Overcast (7-8)	Scattered (1-3)	Broken (4-6)	Overcast (7-8)	Scattered (1-3)	Broken (4-6)	Overcast (7-8)	Scattered (1-3)	Broken (4-6)	Overcast (7-8)
North Bay	1		—	22	4	1	61	6	2	9	—	—	93	10	3
Central Bay	7	—	—	14	6	—	43	2	—	12	1	—	76	9	0
South Bay	9	3	—	19	5	—	27	3	—	19	2	—	74	13	0
Total	17	3	—	55	15	1	131	11	2	40	3	—	243	32	3

43 per cent for the south Bay, 20 per cent for the central Bay and *nil* for the north Bay.

(h) For the year as a whole, the mean height of *Cb* tops is 39,400 ft over the north Bay, 38,400 ft over the south Bay and 38,500 ft over the central Bay.

2.5. Indicated and true heights

According to ICAO regulations, flight separation is based on the standard atmosphere and the sub-scale in pressure altimeters is set to 1013.2 mb after the take off. The altimeter would indicate true height only when the conditions of the standard atmosphere are satisfied. The tropical atmosphere is significantly different from the standard atmosphere. For example, the mean annual level of 300 mb surface at Port Blair in the Andamans is higher by about 1800 ft as compared to the 300 mb level in the ICAN atmosphere. Aircrews normally estimate cloud tops in relation to their flight level. The post flights reports including the pictorial representation in Airep forms would, therefore,

be the indicated heights which may differ from the true height. Over the Bay of Bengal the true heights of *Cb* tops will be higher than the heights estimated in relation to the flight level. The difference between the true and indicated heights can be calculated by reference to the relevant radio-sonde data.

3. Cloud amounts

Very little data about the amount of *Cb* clouds over the Bay of Bengal are available. For flight planning and to avoid last minute detours, it is necessary to know amounts of *Cb* clouds expected along the route. This will be specially important for SST operations, where a change of course to avoid a line of *Cb* may take nearly 100 miles to complete. Amounts of *Cb* clouds observed over the Bay of Bengal were indicated in 278 reports. *Cb* cloud amounts have been tabulated seasonwise and regionwise in Table 4 in three categories, scattered (1-3 octa), broken (4-6 octa) and overcast (7-8 octa).

TABLE 5
Frequency of turbulence near Cb clouds

No. of reports in	Dec-Feb			Mar-May			Jun-Sep			Oct-Nov			Annual		
	Slight	Moderate	Severe	Slight	Moderate	Severe	Slight	Moderate	Severe	Slight	Moderate	Severe	Slight	Moderate	Severe
North Bay	1	—	—	1	1	—	11	14	2	6	0	—	19	15	2
Central Bay	4	—	—	1	2	—	22	11	2	8	6	—	35	19	2
South Bay	6	8	—	5	5	1	9	22	2	4	11	—	24	46	3
Total	11	8	—	7	8	1	42	47	6	18	17	—	78	80	7

It will be observed that the annual frequency of scattered Cb clouds is 87 per cent and that of broken clouds is 12 per cent. The mean Cb cloud amount works out to 3 octas.

It is significant that all the three cases of overcast Cb clouds (7-8) were in the north Bay, two of them during the southwest monsoon season and one in the pre-monsoon season.

4. Weather phenomena near Cb tops

4.1. *Turbulence* — There were 165 reports of turbulence encountered by aircraft in the vicinity of Cb clouds over the Bay of Bengal. The turbulence was slight in 78 cases and moderate on 80 occasions while in 7 cases aircraft were subjected to severe turbulence. Table 5 summarises the frequency of turbulence for the three regions seasonwise.

It is seen that there is a seasonal as well as spatial variation for the incidence of turbulence. Nearly 60 per cent of varying intensities of turbulence are reported during the monsoon. Out of 7 severe turbulences reported 6 are for this season and only one for the pre-monsoon season.

Maximum number of moderate turbulence (46 out of 80) are reported from south Bay area, while that of slight from central Bay. North Bay is the seat of turbulence during the monsoon. It is significant to note that the six severe turbulence reports during monsoon are equally divided spatially over north, south and central Bay.

4.2. *Icing*

12 reports of light icing and one report of moderate icing over the Bay of Bengal were recorded. 10 reports of light icing referred to the southwest monsoon season while the solitary instance of moderate icing was reported in the pre-monsoon season. Of the total 12 light icing reports, 7 were over the north Bay during the

SW monsoon season, 4 over the central Bay and one over the south Bay.

Moderate icing was encountered by an aircraft on a flight from Singapore to Madras on the 26 March 1969 near 60°N, 95°E at 1435 GMT. The flight level was 35,000 ft and the ambient temperature -42°C. There were broken Cb clouds and the Captain estimated the Cb tops to be at 44,000 ft and base at 9000 ft. The aircraft was also subjected to moderate turbulence. On the occasions of light icing, aircraft were mostly flying within 5000 ft of the Cb tops with ambient temperatures generally in the range -36° to -46°C. However in one case, light icing was reported even when the temperature was as low as -56°C.

4.3. *Hail*

There was only one instance of hail. A BOAC aircraft flying at 35,000 ft encountered a severe thunderstorm at 1645 GMT on the 6 June 1969 over the sector Akyab to Calcutta. The thunder storm was accompanied by light icing, moderate turbulence and hail, the estimated height of Cb tops being 45,000 ft.

The present analysis based on post flights reports rendered by skilled and experienced aircrews during the last sixteen years may be taken as fairly representative of normal Cb developments over the Bay of Bengal. However in view of the serious hazard posed by Cb clouds to aviation, it is necessary to obtain more detailed information about Cb clouds in the Bay with the help of specially equipped reconnaissance flights, weather ships and airborne weather radar. Aircrews can also provide additional information about weather phenomena such as turbulence, icing, etc associated with Cb clouds whenever encountered. These measures will help in obtaining a more accurate picture of Cb developments over the Bay of Bengal, which will in turn contribute to greater flight safety.

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