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Cirriform clouds over India — Heights and Temperatures

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ABSTRACT. Aviators and meteorologists alike have now-a-days become increasingly concerned with cirriform clouds. Information regarding the characteristics of cirriform clouds over tropical countries is very meagre. All available data of these clouds obtained by high-altitude aircraft flights over India during the last seven years have been analysed. These include reports of the meteorological reconnaissance flights by the I.A.F. aircraft and Met. reports by civil jet-aircraft. The mean heights of cirriform clouds, their extremes, thickness and amounts have been computed. The diurnal, regional and seasonal variations are also discussed. Other parameters investigated include turbulence, winds, icing and visibility in and near these clouds. A typical synoptic situation giving rise to extensive cirriform clouds is also presented.

1. Introduction

1.1. With the rapid growth of high-speed jet-aviation, meteorologists have become increasingly concerned with winds, temperatures and clouds at high levels. Forecasting of high level clouds has been specially difficult. As one experienced pilot remarked 'It has for long now been our practice to add a minimum of 10,000 ft to all estimate forecasts for the tops of high clouds, and this figure is often insufficient in practice.' Particularly in the tropics, forecasters are greatly handicapped by lack of climatological data in respect of cumulonimbus tops and cirriform clouds, which often extend upto the tropopause. In recent years, some data of *Cb* tops based on aircraft observations and radar studies, have become available in India. Aircraft reports of cirriform clouds indicate that during the monsoon season, thick cirrostratus bases may merge with altostratus and nimbostratus clouds to form a solid cloud mass from 500 ft a.g.l. to 45,000 ft, sometimes with *Cb* cells embedded in these layers. Cirriform clouds with the attendant hazards of severe turbulence, icing and poor visibility may affect the performance of jet-aircraft, specially the supersonic aircraft while climbing. A summary of the data of cirriform clouds, obtained through high-altitude flights across India, is presented in this paper.

1.2. There are three principal genera of cirriform clouds — cirrus (*Ci*), cirrocumulus (*Cc*) and cirrostratus (*Cs*). According to the W.M.O. International Clouds Atlas, cirrus clouds are detached clouds in the form of white delicate filaments or patches or narrow bands. Cirrocumulus clouds are thin white patches, sheets or layers of clouds without shading, composed of very small elements in the form of grains or ripples and regularly arranged. Cirrostratus clouds are transparent whitish cloud veils of fibrous or smooth appearance generally producing halo phenomena. For an accurate climatology of a specific cloud type, it is essential that no other clouds are included by mistake. However quite often from physical appearance alone, it is difficult to differentiate correctly between cirrostratus and altostratus. As a guide, Appleman (1961) has suggested that cloud formations at temperatures below —35° or —40°C would be of the true cirrostratus type, while clouds formed at temperatures above — 30°C and especially above —20°C would be akin to altostratus. In the present study, these criteria have been adhered to.

2. Earlier work

2.1. Initially heights of cirriform clouds were based solely on observations from

ground, by eye or by double theodolite method. The first systematic studies of cirrus heights were made all over the globe as early as in 1896-97, the International Cloud Year (ICY), by the double theodolite method. However high cloud studies received an impetus with the introduction of jet-aircraft, which could penetrate these clouds and provide accurate data. In the last decade detailed analyses of jet-aircraft reports of high clouds have been carried out in Europe and America. These include studies by Murgatroyd and Goldsmith (1956) and James (1955) of the Meteorological Research Flight (MRF) reports over England, by Alt (1958) in respect of France and Western Germany and by Clodman (1957) and Appleman (1956) for Canada and the U.S.A. respectively. The results of the various studies on cirrus clouds have been discussed fully by Appleman (1961) in the *W.M.O. Tech. Note*, 40, which also gives a comprehensive list of references.

2.2. Most of these studies were confined to temperate latitudes and very little information regarding the characteristics of tropical cirriform clouds was available. In India, Narayanan and Manna (1931) carried out a systematic study and obtained mean heights of tropical high clouds, by reference to heights at which pilot balloons were lost in clouds. Based on these studies, the cloud atlas in use in India indicated the mean base of high clouds as 25,000 ft and tops as 35,000 ft. Rao (1955) analysed the post-flight reports of the B.O.A.C. Comet Service over South Asia in 1952-1953. He found that the prevalent estimates of heights of high clouds for the area were too low, by 5000 — 10,000 ft.

3. Data analysed

3.1. Data obtained from ground observations do not provide accurate information of high clouds. Quite often thin veils of cirrus clouds are encountered by aircraft while none is visible from ground. Even thick and extensive cirrostratus layers are invisible from ground if low or medium clouds intervene, as in the monsoon months. The best method of finding the characteristics of cirriform clouds is to obtain reports from aircraft, which either penetrate these clouds or fly close to them. These reports also provide additional information of depth of clouds, temperatures and attendant weather phenomena.

3.2. The present study is, therefore, confined to reports of cirriform clouds over India observed from jet-aircraft, whose operational altitude was 30,000 ft (9 km) or higher. All available post flight reports from civil jet-aircraft operators across India and from the meteorological reconnaissance flights of the Indian Air Force for the last seven years (1957—1963) were scrutinised and the data regarding cirriform clouds extracted. The present analysis is based on a total of 749 reports of cirriform clouds actually observed. Out of these, about ninety per cent were obtained through reconnaissance flights. The observations are spread over most of India, although there is a large concentration of reports from the central parts of India (between Lat. 20°N and 25°N). A large majority of the clouds observed were of the cirrus type and a good number of the cirrostratus type. Cirrocumulus clouds were rare, being less than 2 per cent of all the cirriform clouds observed. This is also in conformity with previous studies.

4. Analysis

4.1. *Heights*

4.1.1. *Heights of Bases* — Over India, the bases of cirriform clouds (Table 1) are mainly between 35,000 and 45,000 ft. Nearly 70 per cent of the observed bases occur between these limits. Less than 10 per cent of the bases are either below 30,000 ft or above 45,000 ft. The average base height for the year is 37,000 ft. The highest base reported was 50,000 ft in cirrostratus clouds in August. There is no significant variation in the mean base heights of cirrus and cirrostratus clouds.

4.1.2. *Heights of Tops* — Table 2 shows the frequency-distribution of heights of tops of cirriform clouds. In 82 per cent cases, the tops of cirriform clouds reached the levels

TABLE 1

Percentage frequency of heights of base of high clouds

Season	Heights (in thousands of ft)						Total No. of obsns.	Mean
	20—24·9	25—29·9	30—34·9	35—39·9	40—44·9	45—50		
	Cirriform clouds (*Ci, Cs, Cc*)							
Winter (Dec—Feb)	16	11	19	40	11	3	74	34
Pre-monsoon (Mar—May)	4	4	28	44	20	0	97	36
Monsoon (Jun—Sep)	1	4	19	42	31	3	226	38
Post-monsoon (Oct—Nov)	0	3	8	63	18	8	38	38
Year	4	5	20	44	24	3	435	37

Highest base — 50,000 ft, Lowest base — 20,000 ft, Mean — 37,000 ft

TABLE 2

Percentage frequency of heights of high clouds

Season	Heights of tops (in thousands of ft)							No. of obsns.	Mean
	20—24·9	25—29·9	30—34·9	35—39·9	40—44·9	45—49·9	50—55		
	Cirriform clouds (*Ci, Cs, Cc*)								
Winter (Dec—Feb)	4	7	17	54	18	0	0	76	36
Pre-monsoon (Mar—May)	2	1	21	40	33	3	0	107	38
Monsoon (Jun—Sep)	1·4	4	10	17	49	18	0·3	292	41
Post-monsoon (Oct—Nov)	0	2	0	49	44	5	0	43	40
Year	2	3	13	30	41	11	0·2	518	40

Highest top — 55,000 ft, Lowest top — 21,000 ft, Mean — 40,000 ft

TABLE 3

Frequency of the thickness of cirriform clouds

Thickness (ft)	Base — Heights (thousands of ft)						Total percentage frequency
	<25	25—29·9	30—34·9	35—39·9	40—44·9	>45	
500 or less	2	0	4	9	4	0	7
1000	3	6	9	42	22	0	28
2000	0	8	14	27	15	0	22
3000	2	4	4	6	8	0	8
4000	0	2	4	8	0	0	5
5000	1	2	10	14	7	1	12
6000	0	0	2	3	0	0	2
7000	1	0	2	9	0	0	4
8000	0	0	1	4	0	0	2
9000	0	1	3	11	0	0	5
10000	0	1	1	2	3	0	2·5
>10000	1	0	3	8	1	0	4·5

Total No. of observations 295, Mean thickness 3600 ft, Max. thickness 17,600 ft

TABLE 4

Percentage frequency

Cloud amounts — cirriform clouds

Season	Scattered 1—3 octa	Broken 4—6 octa	Overcast 7—8 octa	Number of observation	Average coverage (per cent)
Winter	66	18	16	91	43
Pre-monsoon	69	16	15	143	42
Monsoon	40	25	35	355	59
Post-monsoon	38	30	32	53	58
Year	50	22	28	642	53

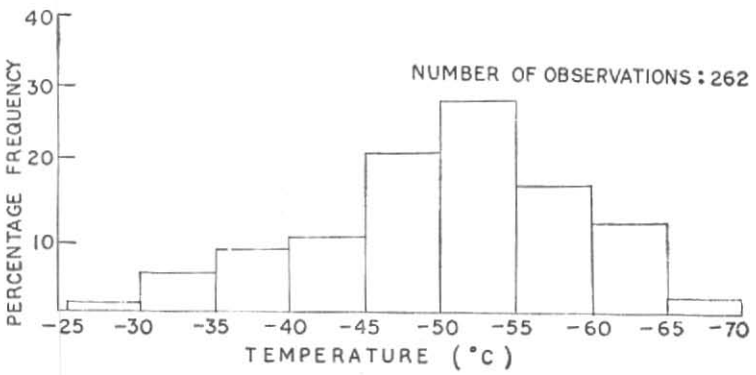

Fig.1. Temperatures at base of cirriform clouds

between 35,000 and 50,000 ft. The mean height of the cirriform cloud tops is 40,000 ft. Cirrus tops tended to be higher than cirrostratus tops. The highest cirrus top observed was 55,000 ft in July.

4.1.3. *Thickness* — There were 295 reports where heights of bases and tops of cirriform clouds were simultaneously available. Cloud thickness varied from 500 ft to 17,000 ft. Table 3 indicates thickness distribution at intervals of 1000 ft. The thickness of clouds was 5000 ft or less in 82 per cent of cases, the average thickness value being 3600 ft. Thickness level of 1000 ft had the highest frequency (28 per cent).

From Table 3, it will be evident that most of the thicker clouds (with thickness 6000 ft or higher) have bases between 30,000 and 40,000 ft.

4.2. *Cloud amounts*

4.2.1. Climatological summaries of high cloud amounts are based on visual observations from the ground. As mentioned in para 3.1, surface estimates of high cloud amounts are often underestimates. This is particularly so in India during the monsoon months, when extensive low and medium cloud layers often screen off high clouds from surface-view.

4.2.2. In 642 observations, high cloud amount was also included. These were tabulated as scattered (N=1, 2, 3 octa), broken (N = 4, 5, 6 octa) and overcast (N = 7, 8 octa). These are given in Table 4. Using the midpoint of each 'amount group' as representative of the mean value, the average coverage of cirriform clouds, when present, was calculated. The average coverage of cirriform clouds when present for the year works out to be 53 per cent in India as compared to 55 per cent in the U.S.A. and 63 per cent in Western Europe.

4.3. *Temperatures — Base and Top*

4.3.1. Temperatures at the bases and the tops of cirriform clouds were extrapolated from the recorded temperatures at the cruising levels of the aircraft. A lapse rate of 2°C per thousand feet, which corresponds to the average lapse rate at 12 km over the Indian latitudes, was assumed. In many cases aircraft flew within 2000 — 5000 ft of the high clouds and hence the calculated temperatures may be considered fairly representative.

4.3.2. Frequency distribution of temperatures at the bases and tops of high clouds are given in Figs. 1 and 2. The most common temperatures for the bases ranged from —45° to —55°C while those for the tops were between —55° to —65°C. The base-temperatures ranged from —25° to —70°C while the temperatures at the tops extended from —26° to —85°C. The mean temperatures at the bases and tops of cirriform clouds are —50° and —56°C respectively.

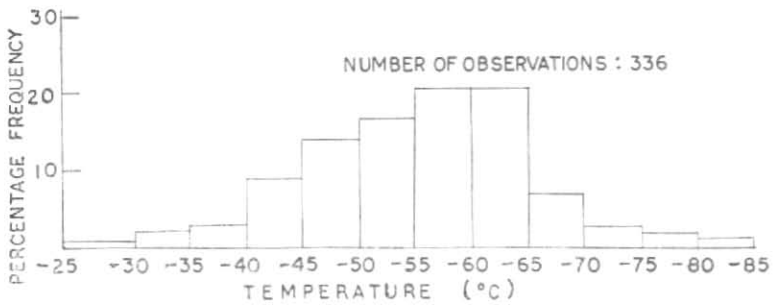

Fig. 2. Temperatures at top of cirriform clouds

4.3.3. Clodman (1957) had deduced that the temperatures at the bases of cirrus clouds would tend towards —40°C, on the hypothesis of Ludlam that there is a rapid increase in the number of active nuclei below a temperature of about —40°C. The mean temperature of bases in Canada was —39°C. However, in India the high cloud base-temperatures appear to be much lower than those in the temperate latitudes.

4.4. *Variations — diurnal, regional and seasonal*

4.4.1. *Diurnal and Regional variations*— The heights of all cirriform clouds were rearranged according to the times of observation and region. An analysis of the results shows that cirriform cloud bases tend to be slightly higher in the afternoons (1130—1730 IST) as compared to those in the mornings (0530—1130 IST). Averaged over the year, high cloud bases are higher by 1000—1500 ft over the southern (south of lat. 20°N) and central (20°N—25°N) as compared to those in northern India (Table 5).

4.4.2. *Seasonal variation* — Tables 1 and 2 show that both the bases and tops of cirriform clouds are higher by 4000 — 5000 ft during the monsoon months (June to September) as compared to the winter months (December to February). These results are in fair agreement with those of Alt (1958) who found the mean values of bases and tops lowest in February and highest in September. Appleman (1956) also arrived at a similar conclusion. As regards thickness, almost all the instances of thickness of 10,000 ft or higher were in the monsoon months. Cirriform cloud amounts are also maximum during the monsoon months (Table 4).

4.5. *Associated weather phenomena*

4.5.1. *Turbulence, winds, icing* — Out of 101 cases when turbulence was experienced in or near cirriform clouds, it was slight in 47 cases, moderate in 43 cases and severe in 11 cases. Details of severe turbulence encountered are given in Table 6. No sudden wind-shifts were reported in high clouds and these winds were in fair agreement with the prevailing winds. There was only one instance of icing reported. In July 1959, an aircraft flying in cirrus clouds at an altitude of 35,000 ft, about 2000 ft below the cirrus top, had its canopy slightly iced up at a temperature of —32°C. It would, therefore, appear that icing in cirriform clouds is a rare phenomenon in India. This agrees with Alt's (1958) inference for Western Europe.

4.5.2. *Visibility* — Both horizontal and vertical visibility observations were recorded during meteorological reconnaissance flights. Generally while flying above or through thin cirriform clouds, horizontal and vertical visibility was good. However, while flying through or just above thick cirrus or cirrostratus clouds visibility was often restricted. In a few cases *nil* visibility was reported while flying through high

TABLE 5

Regional variation — cirriform cloud bases

Percentage frequencies

Season		Base heights (thousands of ft)						Mean base (1000 ft)
		20–24·9	25–29·9	30–34·9	35–39·9	40–44·9	45–50	
Winter	N	16	16	26	31	11	0	32·5
	C	17	9	15	38	15	6	34·5
	S	17	0	12	65	6	0	34·5
Pre-monsoon	N	0	0	33	56	11	0	36·5
	C	0	3	23	51	23	0	37·5
	S	23	12	41	12	12	0	31·5
Monsoon	N	9	0	0	36	55	0	39·0
	C	0	3	17	46	30	4	38·5
	S	3	5	21	39	30	2	37·5
Post-monsoon	N	0	0	33	67	0	0	36·0
	C	0	8	8	38	31	15	39·5
	S	0	0	9	74	13	4	38·2
Year	N	8	6	23	43	20	0	36·0
	C	3	5	18	45	25	4	37·5
	S	6	5	20	43	24	2	37·0

Total No. of observations
N (Northern India north of 25°N) = 51
C (Central parts between 25°N and 20°N) = 198
S (Southern India south of 20°N) = 182
Total = 431

clouds. Another factor which restricts the vertical visibility in India is the haze during the monsoon months and dust-haze in premonsoon months over northern India, the haze layers sometimes extending up to the mid-troposphere. Clodman (1957) found that on 70 per cent of flights through cirrus clouds in Canada the visibility was 1 mile or less. However over England Murgatroyd (1956) has mentioned that visibility was not a serious limiting factor even for formation flying in high clouds.

5. A typical synoptic situation

5.1. *22 June 1962* — On the morning of 22 June 1962, an upper air low extending upto 4 km had developed over Gangetic West Bengal and neighbourhood. The axis of the monsoon trough on sea level chart lay from Ambala to Calcutta through Varanasi. Fig. 3 shows the isobaric sea level chart at 0830 IST. Stations and ships reporting cirriform clouds at the time are also plotted. The 300-mb chart (Fig. 4) shows an anticyclone over Rajasthan and a well marked thermal low near the south Andaman Sea.

5.2. Meteorological reconnaissance flights on the day showed extensive cirriform clouds over an area exceeding 200,000 sq. miles in the central parts and southern India (Fig. 5). Skies were mostly overcast with cirrus clouds south of Lat. 23°N and east of Long. 75°E.

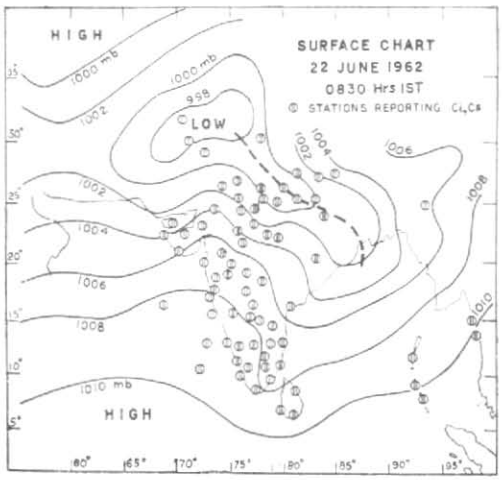

Fig. 3

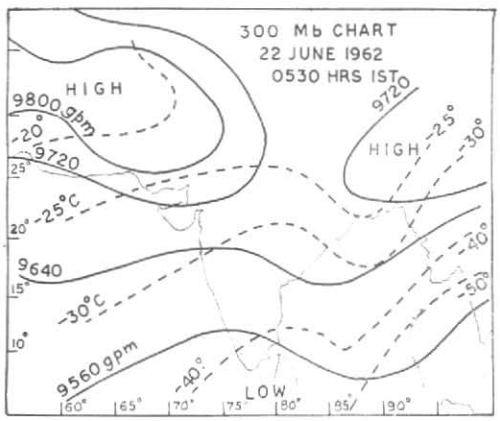

Fig. 4

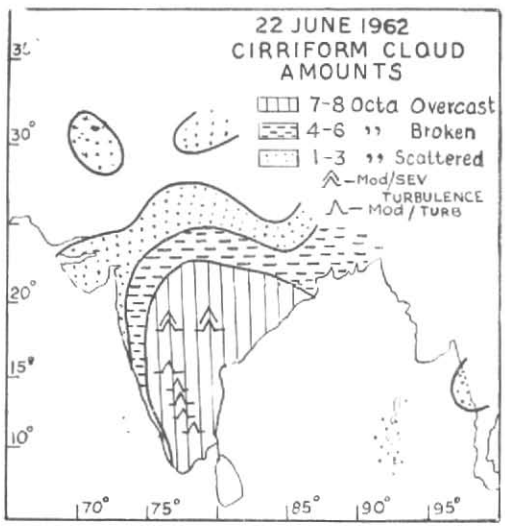

Fig. 5

TABLE 6

Severe turbulence encountered in and near cirriform clouds

Date	Time	Position		Aircraft Fl. Alt.	Clouds			Wind direction (°)/speed (kt)	Remarks (Turbulence)
		°N	°E		Amt/ Type	Base	Top		
	(IST)			(ft)		(ft)	(ft)		
27-11-59	1030	15 15	75 40	38000	8/8 *Cs*	38000	—	195/25	Moderate/Severe
27-11-59	1040	15 00	76 10	38000	8/8 *Cs*	38000	—	120/40	Moderate/Severe
27-11-59	1205	10 50	76 10	40000	8/8 *Cs*	39000	—	125/50	Severe
27-11-59	1225	13 20	75 30	40000	8/8 *Cs*	39000	—	125/50	Severe
23-9-60	1210	17 50	83 00	43000	3/8 *Ci*	—	44000	135/20	Severe
8-10-60	1224	09 10	76 00	41000	6/8 *Ci*	—	37000	090/40	Severe
21-6-61	1055	12 25	79 24	44000	8/8 *Cs*	—	44000	060/50	Severe in clouds
22-6-62	1055	18 15	79 03	48000	8/8 *Ci*	40000	49000	090/73	Moderate/Severe in clouds
22-6-62	1165	18 22	77 30	48000	8/8 *Ci*	40000	49000	095/88	Moderate/Severe in clouds
4-1-63	0915	19 00	74 30	36000	2/8 *Ci*	42000	43000	320/10	Severe at 36,500 ft
18-6-63	1945	15 20	75 35	38000	3/8 *Ci*	37000	38000		
					2/8 *Cb*	—	35000	060/15	Severe at 38,000 ft Slight at 41,000 ft

Clouds were highest between latitudes 14°N and 20°N with bases at 40,000 ft and tops 49,000 ft. An aircraft flying 1000 ft below the top along latitude 18°N encountered moderate to severe turbulence between Long. 77°E and 79°E. The easterly jet-stream also accelerated westwards from 63 knots near 80°E to 95 knots at 48,000 ft near 18°N, 76°E. Over Madras and Mysore States, though cirrus tops were lower at 47,000 ft the thickness increased to 12,000 ft. Moderate turbulence was continuously encountered, while flying at 42,000 ft, 5000 ft below cirrus tops. Visibility was poor, throughout.

5.3. This is a good illustration of how widespread and thick cirriform clouds can be even on a day of weak monsoon conditions over south India.

6. Summary

(*a*) The average heights of bases of cirriform clouds over India are 37,000—40,000 ft and those of tops are 40,000—43,000 ft. These are considerably higher than those in temperate latitudes.

(*b*) The bulk of cirriform clouds have thickness 5000 ft or less. Clouds with bases higher than 40,000 ft are comparatively thinner.

(*c*) The average coverage of cirriform clouds is 53 per cent in India as compared to 63 per cent in Western Europe.

(*d*) The mean temperatures at the bases and tops of cirriform clouds are —50° and —56°C respectively, though temperatures as low as —85°C have been recorded in these clouds.

(*e*) There is a large seasonal variation in the characteristics of cirriform clouds in India. As in the temperate latitudes, both the bases and tops are highest during the period June to September. Cirriform clouds are also thicker and have higher coverage in this season.

7. Acknowledgement

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