J2.2 STUDY OF RADAR BRIGHT BAND OVER A TROPICAL STATION

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ABSTRACT

We herein report on our study of freezing level height (HFL) and radar bright band height (BBH) at Trivandrum, a tropical station in India. We also report the height of peak cloud liquid water level (HPCL). We have made a particular effort to determine the relative positions of HFL, BBH and HPCL at the station. An effort has been made to find out whether the HPCL corresponds to the bright band peak. We also discuss the occurrence of stratiform/convective rain on the basis of the relative position of HFL, BBH and HPCL. We present the results of validation of HFL data recorded by precipitation radar (PR) on board Tropical Rain Monitoring Mission (TRMM) against ground truth.

1. INTRODUCTION

According to the information available in open literature the transition height between liquid particles below and freezing particles above is close to the 0^0C isotherm height (freezing level height) in stratiform rain, while in convective rain the transition height is expected to go above the freezing level height (HFL) because of large scale mixing of different particle types. Strong vertical air motion in convective cells lifts up liquid drops upward leaving them in super cooled state (Battan 1973).

Stratiform rain has been reported to be associated with bright band (Steiner et al. 1995; Bringi and Chandrasekar 2001). Bright band is a region of enhanced reflectivity in the back scattered signal of the radar. It appears 'bright' because of the increased reflectivity normally below the HFL as compared to above and much below it. The region below the bright band consists of liquid state, while that above the HFL consists of solid phase, i.e., ice particles. The bright band region consists of snow flakes, i.e., water coated ice particles. Water having higher dielectric constant than ice produces greater reflectivity in the bright band region as compared to above it. Though the region below the bright band consists of liquid particles alone, the fall velocity of liquid drops being very high, the number of reflecting particles per unit volume is very less in this region as compared to the bright band region, thereby reducing the reflectivity (Fabry and Zawadzki 1995; Battan 1973). In many parts of the globe bright band has been reported to occur below the HFL (Battan 1973; Bauer 2003). However, peak reflectivity level at the height of the HFL has also been reported (Donaher 2009).

In this paper an attempt has been made to study the bright band height (BBH) and HFL at Trivandrum. A particular effort has been made to find out whether the cloud liquid water (CLW) contributes to the peak reflectivity. Relative positions of the bright band, HFL and the peak cloud liquid water level (HPCL) have been studied in relation to stratiform and convective rain. Section 2 describes data base. Results and discussion

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have been mentioned in section 3. Conclusions are listed in section 4.

2. DATA BASE

We obtained CLW, BBH and HFL data from the Tropical Rain Monitoring mission (TRMM) satellite. The CLW data are the level 2 products of TRMM microwave imager (TMI) onboard TRMM listed in the file 2A12. The BBH, HFL and rain type data are the level 2 products of the precipitation radar (PR) onboard TRMM listed in the file 2A23. The data were obtained in the Hierarchical Data format (HDF) and were converted to ASCII for further analysis. It is noteworthy that the scan time of the file 2A12 and 2A23 do not exactly match on a particular day, rather differ by a gap of about 30 minutes to ten hours. HFL values were also obtained from NOAA as a ground truth and were compared with that from TRMM.

3. RESULTS AND DISCUSSION

In this study an assumption has been made that HPCL remained the same when CLW, BBH and HFL were recorded. This assumption does not seem to produce any error since HPCL mostly remains the same at Trivandrum throughout a month and even throughout a year (Sen et al. 2010).

It is found from the study that out of 54 days when TRMM recorded rainfall in the year 2007, only on 12 days bright band was observed. In the year 2008 TRMM recorded rainfall on 36 days, while bright band was detected on 11 days alone. In fact, many of the rainfall events were not recorded by TRMM as there was no pass. Hence occurrence of bright band could not be detected though it might be present. Moreover, there were cases when TRMM missed to record bright band data. Such cases are marked by '- 8888' in the BBH data file 2A23 (http://trmm.gsfc.nasa.gov. 1998). In 2008 bright band was recorded for 2 days in March, 2 days in April, 5 days in July and 3 days in October. In 2007 bright band was recorded for 3 days in May, 6 days in June, 3 days in July, 1 day in August and 2 days in November. BBH for different months for the year 2007 and 2008 are given in Table 1. Table 1 shows that in the year 2007 maximum and minimum BBH were found in May and November respectively, while in the year 2008 the maximum and minimum BBH were observed in the month of October and March respectively.

Table 1. Occurrence of BBH, HFL and HPCL at Trivandrum

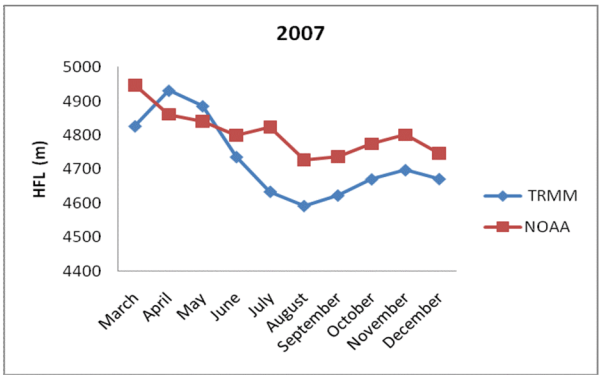
Date	Scan time of BBH and HFL	BBH (m)	HFL (m)	HFL-BBH (m)	Scan time of CLW	HPCL (m)	Range of HFL – HPCL (km)	Rain type
30-4-07	1:58:22	3070	4928	1858	11:21:28	0 CLW	-	Startiform
26-5-07	15:45:57	4149	4842	693	21:44:40	2.5-3.0, 3.0-3.5	1-1.5, 0.5-1.0	Startiform
29-5-07	11:31:35	4372	4820	448	20:35:44	2.5-3.0	2-1.8.0	Startiform
30-5-07	11:32:04	4146	4820	674	19:39:39	3.5-4	1.3-0.8	Startiform
18-6-07	15:16:40	4261	4720	459	10:12:24	3-3.5	1.7-1.2	Startiform
21-6-07	16:39:09	3927	4708	781	9:04:09	2.5-3, 3-3.5	2.2-1.7, 1.7-1.2	Startiform
22-6-70	11:36:12	4748	4706	-42	8:8:40	4-4.5	0.7-0.2	Startiform
17-7-07	7:29:11	3796	4615	819	6:17:46	3-3.5, 3.5-4	1.7-1.2, 1.2-0.7	Startiform
21-7-07	3:43:42	4402	4612	210	4:13:02	3-3.5	1.6-1.1	Startiform
25-7-07	4:49:20	4315	4607	292	2:08:21	3-3.5	1.6-1.1	Startiform
31-8-07	10:22:47	4190	4597	407	7:12:09	3-3.5	1.6-1.1	Startiform
5-11-07	10:04:55	4056	4695	639	11:41:07	0 CLW	-	Startiform
9-11-07	6:40:38	3035	4698	1663	9:37:17	0 CLW	-	Startiform
11-3-08	16:38:04	4180	4799	619	18:41:55	0 CLW	-	Startiform
22-3-08	23:40:57	3859	4851	992	13:25:30	3-3.5	1.79-1.29	Startiform
9-4-08	8:33:08	3925	4925	1000	14:48:14	0 CLW	-	Startiform
13-4-08	4:28:49	4219	4945	726	2:50:56	0 CLW	-	Startiform
15-7-08	22:25:13	4144	4620	476	NA	NA	-	Startiform
19-7-08	12:10:51	3937	4618	681	1:29:02	3-3.5	1.6-1.1	Startiform
23-7-08	7:58:07	4504	4602	98	9:15:26	3-3.5	1.6-1.1	Startiform
26-7-08	8:53:40	4431	4610	179	8:3:36	0 CLW	-	Startiform
19-10-08	13:27:37	4305	4678	373	NA	NA	-	Startiform
20-10-08	8:17:17	4716	4679	-37	12:9:4	2.5-3, 3-3.5	2.1-1.6, 1-67-1.1	Startiform
24-10-08	4:03:12	4450	4682	232	0:11:54	4-4.5	0.6-0.1	Startiform

Monthly maximum and minimum HFL values obtained from TRMM are shown in Table 2. It is found from Table 2 that HFL has daily, monthly and yearly variations. Same result is found by other researchers (Sarkar et al. 1996; Sen et al. 1997). It is also found from Table 2 that in the year 2007 and 2008 average HFL was maximum in the month of April and the minimum was observed in the month of August. In the year 2007 the maximum HFL of 4958 m was recorded in April and a minimum of 4582 m was recorded in August. In 2008 the maximum HFL of 4952 m was recorded in April, while a minimum of 4583 m was recorded in August.

Table 2. Monthly maximum and minimum HFL at Trivandrum

Year	Month	Maximum HFL (m)	Minimum HFL (m)
2007	March	4876	4755
	April	4958	4892
	May	4924	4820
	June	4801	4680
	July	4671	4604
	August	4606	4582
	September	4595	4646
	October	4688	4650
	November	4704	4691
	December	4689	4650
2008	March	4884	4762
	April	4952	4896
	May	4926	4833
	June	4813	4679
	July	4663	4610
	August	4604	4583
	September	4638	4593
	October	4691	4646
	November	4704	4692
	December	4688	4654

Figure 1 shows the comparison of monthly average HFL value recorded by TRMM and NOAA. It is found from Fig.1 that HFL values recorded by NOAA mostly over estimated that measured by TRMM. However, in some cases the reverse was true.



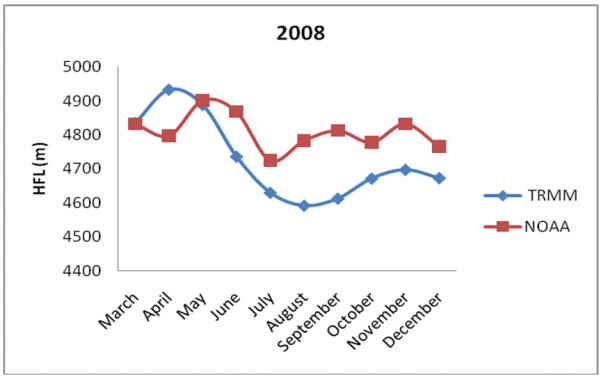


FIG. 1. Comparison of average freezing level height over Trivandrum (TRMM &NOAA).

Table 1 shows the positions of BBH, HFL and HPCL for 2007 - 2008 at Trivandrum. It is seen that BBH mostly lay below HFL by 98 -1663 m. The exception was found on 22 June 2007 and 20 October 2008 when BBH was 42 m and 37 m above HFL respectively. This observation indicates that on these two days water coated ice particles existed above HFL. It is noteworthy that on these two days PR identified the corresponding rain event as stratiform rain. Table 1 also shows the HPCL values. It is found that HPCL lay below BBH on most of the days. The observation that HPCL mostly lay below BBH indicates that the liquid phase lay much below the BBH. This further indicates that the high reflectivity in the bright band region is not due to liquid particles. Battan (1973) has reported that as compared to above HFL (where there is only snow) and much below it (where only liquid state exists), just below the HFL radar records an enhanced reflectivity, giving rise to bright band.

However, on 8 November 2007 HPCL was found to occur at 4 - 4.5 km, while HFL was found at 4.39 km as recorded by NOAA, indicating that on that day liquid phase existed at the HFL, i.e., super cooled liquid particles existed at the HFL probably indicating a deep convective rain. But this could not be crosschecked as on 8 November 2007 no data were available from file 2A23 of PR.

It is further found from Table 1 that a confirmed stratiform rain is always associated with bright band and in case of stratiform rain HFL lay at the topmost height followed by BBH, while HPCL lay below BBH. In case of convective rain no bright band was seen and HPCL was found to lie below HFL (not shown in Table 1). However, on most of the days when PR recorded a convective rain, TMI recorded 0 CLW values. It is found that mere presence of bright band does not confirm stratiform rain though in most of the cases it does so as shown in Table 1. In fact, Table 1 shows the cases of confirmed stratiform cases alone. On 3 days, viz, 30 April, 5 November and 9 November 2007 presence of bright band was associated with rain type 130 (http://trmm.gsfc.nasa.gov. 1998) which states that it might be stratiform confirmed by V-profile method (Okamoto et al. 1998) but H-pattern method which is based on the University of Washington Convective/Stratiform Separation method (Steiner et al. 1995) confirmed it as convective rain. Kiran et al. (2006) have concluded that if bright band is associated with no turbulence above melting layer then certainly it is a stratiform case, while if bright band is found to occur along with turbulence above melting level then it is a mixed stratiform/ convective case. Moreover, there were cases when rain type flag indicated a probable stratiform case but no bright band was detected (not shown in the text).

We have analysed the cases in which no bright band was detected. It is found that the absence of bright band was associated with the following cases:

Noise/ cloud but not rain
Stratiform rain but bright band was not detected
Convective rain
Transition rain
Something else.

Kiran et al. (2006) reported that if absence of bright band is found to be associated with presence of hydrometeors above melting level then it is a deep convective, else it is a shallow convective case.

4. CONCLUSIONS

HFL measured by TRMM and NOAA differ. HFL shows daily, monthly and yearly variations. A stratiform rain is always associated with a bright band, while a convective episode is characterized by absence of bright band. It is further found that during a stratiform rain event the BBH lies below HFL, while the HPCL is further below. However, in some stratiform cases, water coated ice particles may exist above HFL, marked by higher BBH than HFL, as observed on 22 June 2007 and 20 October 2008. Moreover, liquid phase may exist above HFL, marked by higher HPCL than HFL as seen on 8 November 2007. Thus CLW has no role in producing the bright band as HPCL lies well below BBH in most of the cases. However, in certain cases super cooled liquid drops may exist above HFL marked by higher HPCL than HFL as observed on 8 November 2007.

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