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Detection of Bright Band Heights from Vertical Profile of Radar Reflectivity in Akure, South Western Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Author YBL conceived the research and prepared the layout. Author ETO extracted the raw data while author YBL ran the data analysis. Both authors prepared the first draft of the manuscript. Author ETO handled the introduction, literature review and methodology sections. Author YBL wrote the discussion and conclusion. Both authors proof read and approved the final manuscript.

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ABSTRACT

Bright band is an important phenomenon that occurs in radar observations of precipitation. It is a layer of intense reflectivity caused by the melting of the snowflakes in the atmosphere. Accurate detection of bright band and its associated properties are essential for the estimation of precipitation rates and characterization of precipitation types as required in Agriculture, Aviation, Navigation, Telecommunication sectors etc. Bright Band Height (BBH) is a vital parameter in the determination of rain height, rain-induced radio signal attenuation and mitigation techniques. This paper presents an empirical study on the measurement of BBH and Zero Degree Isotherm Height (ZDIH) from Micro Rain Radar (MRR) data obtained in Akure, Nigeria. Vertical profile of radar obtained during stratiform rainy events were examined to detect bright bands and its features. Analysis of the result showed that the ZDIH varies between 4.48 and 4.60 km while the BBH also

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vary from 4.16 to 4.48 km during intense rainy events in September and October 2010. The derived propagation data would be needed for the optimization and improvement of quality of service (QoS) offered by earth-space links during rainy events in Akure and its environs.

Keywords: Bright band; precipitation rates; rain height; rain-induced attenuation; BBH; ZDIH.

1. INTRODUCTION

Radar is a powerful tool used for remote sensing of the atmosphere, particularly in weather forecasting, monitoring and detection of distant objects. One of the most significant applications of radar in weather monitoring is the detection of precipitation. Radar sends out electromagnetic waves that bounce off precipitation particles in the atmosphere, and the resulting echoes are used to determine the location, intensity, type and motion of precipitation [1]. Radar reflectivity is a measure of the strength of these echoes, and it is commonly used to estimate the intensity of precipitation.

In the study of Radar reflectivity profile, a special range of altitude where refractivity values vary significantly is known as the bright band (BB). The BB is a region of enhanced radar reflectivity caused by a phase change in the physical properties of precipitation particles as they fall through the freezing level of the atmosphere. Specifically, as precipitation particles, such as snowflakes and ice crystals, fall through the freezing level, they begin to melt and merge with other particles, forming larger raindrops. This process results in an increase in the size of the precipitation particles, which, in turn, leads to an increase in the radar reflectivity of the precipitation [2]. The presence of BB is one of the most striking features of radar reflectivity profile. It is a horizontal band of high reflectivity that occurs in the melting level of hydrometeors. It occurs when the precipitation falls through a layer of sub-freezing temperatures and partially melts, forming a layer of mixed-phase particles. This layer has a higher reflectivity compared to the surrounding precipitation particles, resulting in the BB signature in the radar reflectivity profile [2-3]. The BB phenomenon remains one of the most studied features of radar reflectivity in precipitation research owing to its importance and implications. The temperature of the top of BB is assumed to be roughly 0^{o} C, hence, the nomenclature zero degree isotherm height (ZDIH). The BB is usually present below the ZDIH during stratiform precipitation but it is mostly absent during convective cloud [4-5]. The mid-point of the BB is usually detected with the observation of maximum radar reflectivity and it is called bright band height (BBH) as indicated in Fig. 1.

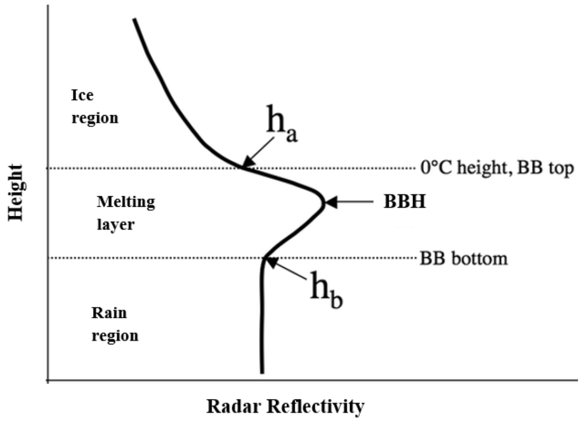

Fig. 1. Illustration of the vertical profile of radar reflectivity

The detection of the bright band height is essential in precipitation research as it provides information on the precipitation type, the vertical distribution of precipitation particles, and the thickness of the melting layer. The height of the bright band can also be used to estimate precipitation amount, which is crucial for hydrological applications [6]. The BBH and ZDIH is a location-dependent parameter which vary spatially hence, it is more accurate when measured locally [7].

The purpose of this research was to study, detect and measure the BBH from the vertical profile of radar reflectivity in Akure, South Western Nigeria, using the Micro Rain Radar (MRR) Data. The research also measured ZDIH and compared the results with previous works. The significance of this study lies in the fact that radar rainfall estimates are widely used in hydrological and meteorological applications, such as flood forecasting, drought monitoring, and water resource management. The bright band height and zero degree isotherm heights play significant role in the estimation of rain heights and rain-induced attenuation in satellite communication [8-9]. Accurate detection of the height of the bright band is crucial for improving the accuracy of radar rainfall estimates and mitigating the impacts of extreme weather events.

Various techniques and algorithms have been developed to detect the bright band height from radar reflectivity profiles. One of the widely used techniques is the vertical profile analysis, which involves analyzing the vertical distribution of reflectivity in the radar signal. The bright band height is determined by identifying the maximum reflectivity value in the profile, which corresponds to the melting layer height [2-3].

2. METHODOLOGY

The available one-year data (2010), employed for this research is an archived data retrieved from the MRR installed at the Observatory Garden of the Communication Physics Research Group (CPRG) at the Federal University of Technology, Akure (FUTA), Nigeria. The observatory garden has a coordinate of 7° 15'N, 5° 15'E and altitude of 358 m above mean sea level [10]. The MRR is a vertically-pointing radar operating at 2.4 GHz [11]. It has a temporal resolution of 1 minute obtained by integrating reflectivity measured over every 10s. It has a vertical resolution of 160 m measurable up to 4.8 km above sea level [12]. The vertical profile analysis is performed by averaging the reflectivity values over successive height bins of 160 which is executed by the algorithm embedded in the MRR.

The retrieved raw data which are in txt format were converted to excel format (.xls) by importing them to the Microsoft Excel application. Radar reflectivity (in dBz) and altitude (in meters) were extracted and sorted into months to identify the wet months, rainy days and period of intense rainfall. The reflectivity was plotted against altitude and analyzed for the presence of a bright band as described subsequently.

The bright band region begins from altitude where the reflectivity increases sharply and apparently returns to its initial value as indicated in Fig. 1 [13]. The bright band height which correspond to the melting layer height is identified as the altitude where the reflectivity reaches its peak value.

3. RESULTS AND DISCUSSION

3.1 Vertical Profile of Radar Reflectivity

The date and time of the rainy events were extracted and sorted from the available data. The graph of radar reflectivity against altitude were plotted for the extracted rainy events and the results are presented in Figs. 2-5. The heights of the bright bands detected during some rainy events in the selected days are the altitudes of maximum radar reflectivities as shown in Figs. 2a, 3a, 4a, and 5a. The corresponding daily mean values are also presented in Figs. 2b, 3b, 4b, and 5a.

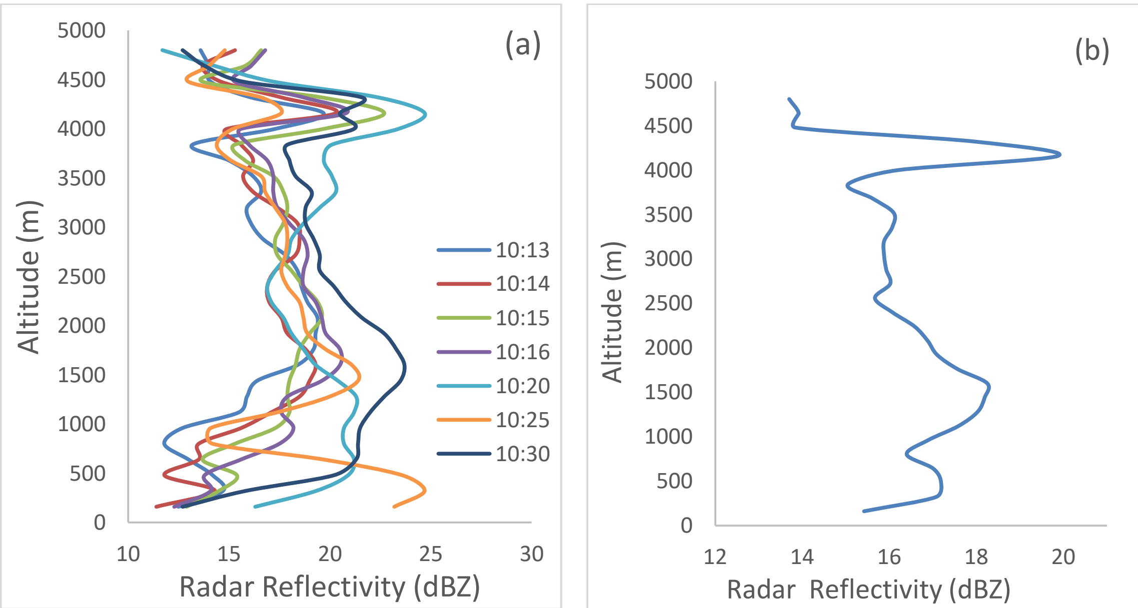

Fig. 2. Vertical profile of radar reflectivity for; (a) a typical rainy day, September 3, 2010 (b) the average value of the rainy day

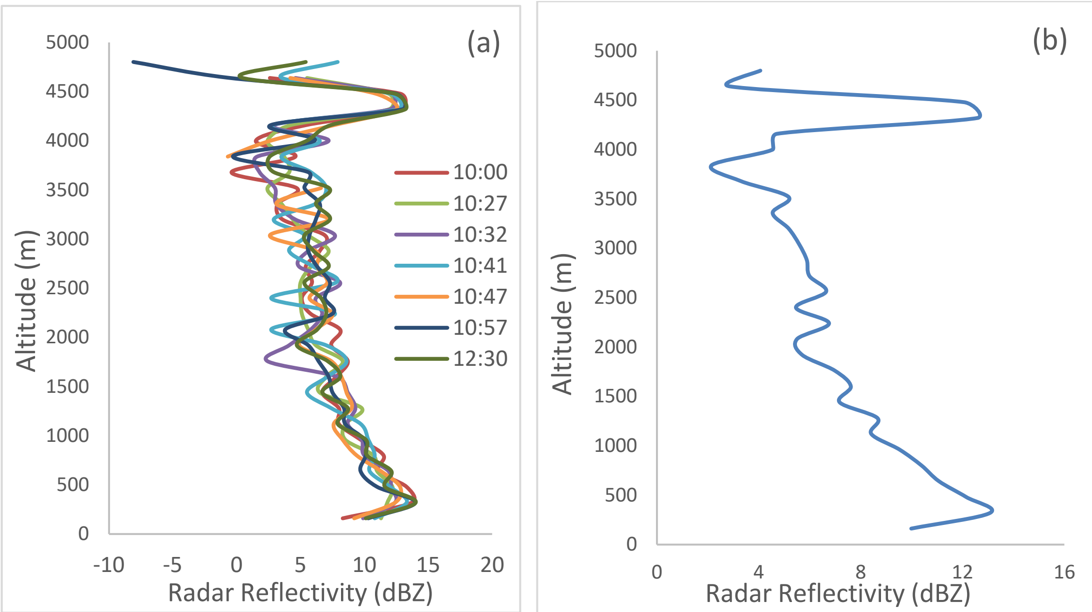

Fig. 3. Vertical profile of radar reflectivity for; (a) a typical rainy day, September 21, 2010 (b) the average value of the rainy day

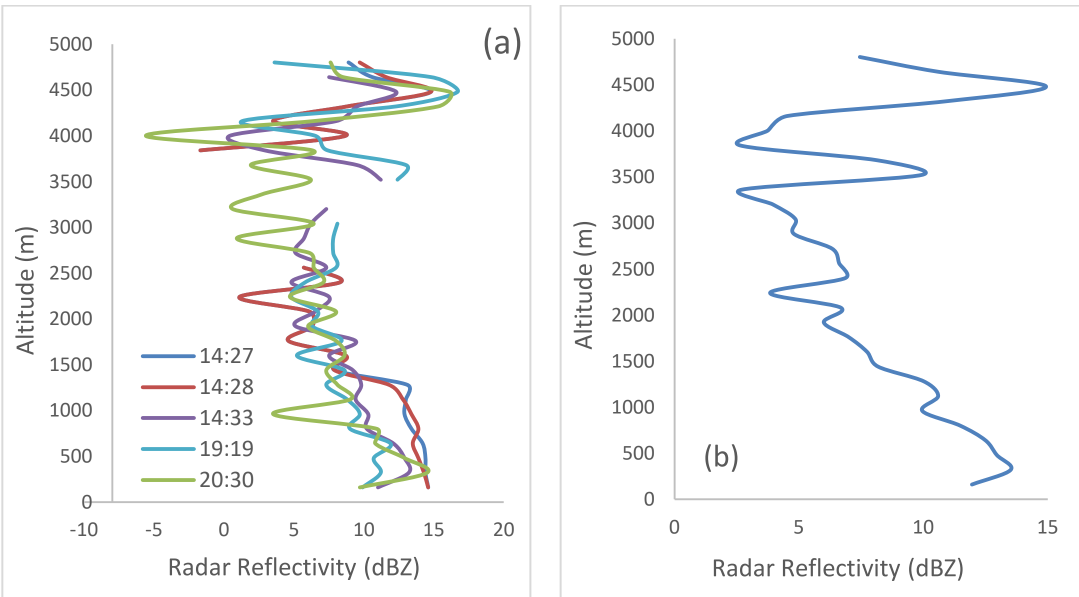

Fig. 4. Vertical profile of radar reflectivity for; (a) a typical rainy day, October 7, 2010 (b) the average value of the rainy day

The nature of the graphs depict the expected trend of vertical radar reflectivity profiles as enumerated in several literatures. The three distinct layers (Rain, Melting and Ice regions) are well defined in all the graphs including the BBHs and ZDIHs as illustrated in Fig. 1.

A close observation of these curves reveals that the top of melting layer (i.e ZDIH) varies from about 4.48 to 4.80 km while the BBH varies from about 4.16 to 4.48 km for the days that BBs were present as presented in Table 1. The differences between the daily means of the BBH and ZDIH lies between 320 and 480 m. This is in agreement with some previous researches which also reported varying differences between 300 m - 500 m in the tropics (Austin 1950 [14], Harris et al., 2000 [15], Awaka et. al., 2009 [16], Olurotimi et al., 2017 [17]).

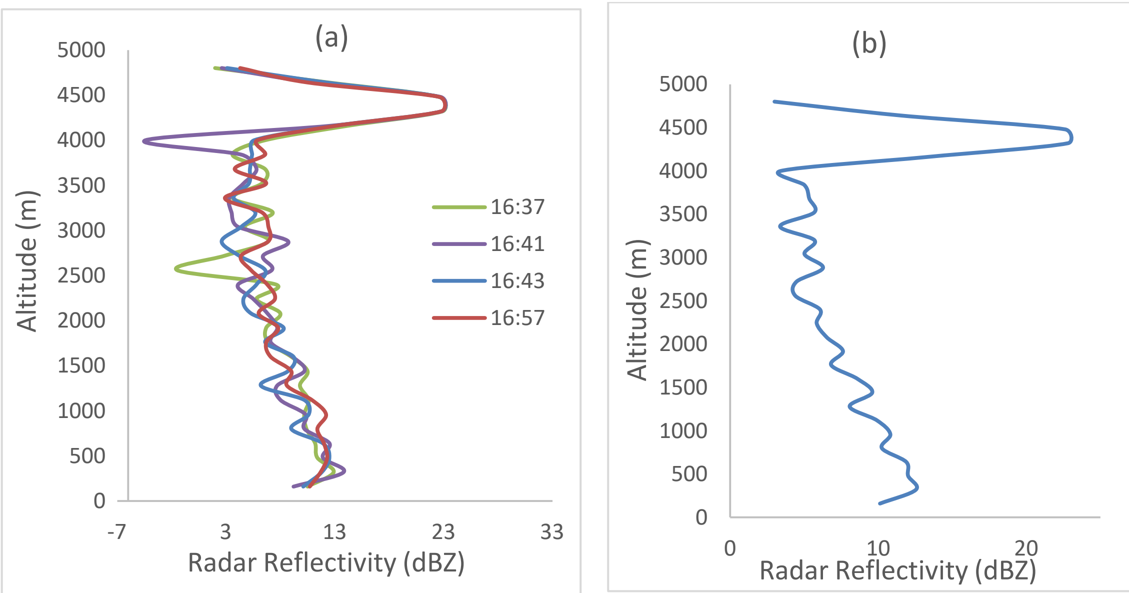

Fig. 5. Vertical profile of radar reflectivity for; (a) a typical rainy day, October 28, 2010 (b) the average value of the rainy day

Table 1. The BBH and ZDIH observed during some selected rainy days

Intense Rainy Days	BBH (m)	ZDIH (m)	Difference (m)
September 3, 2010	4160	4480	320
September 21, 2010	4320	4640	320
October 7, 2010	4480	4800	320
October 28, 2010	4320	4800	480

Table 2. Comparison of ZDIH from two difference sources

Intense Rainy Days	ZDIH from MRR	ZDIH from GPM	Percentage Difference (%)
September 3, 2010	4480	4828	7.2
September 21, 2010	4640	4873	4.8
October 7, 2010	4800	4914	2.3
October 28, 2010	4800	4892	1.9

3.2 Comparison between the ZDIH Obtained from the MRR and GPM Data

The available daily mean values of the ZDIH from the MRR were compared with the corresponding ZDIH from the GPM and presented in Table 2. Comparison shows that the GPM values are slightly higher for all the days with an average percentage difference of about 4.05%. The daily percentage differences are less than 10% for all the rainy days considered hence, the GPM data is recommended for estimation of rain heights and rain-induced attenuation in the absence of ground-measured MRR Data.

4. CONCLUSION

The research studied the observation and detection of bright band for some selected rainy events in September and October 2010. The mean values of vertical profile of the radar reflectivity reveals the top of the bright band (ZDIH) and the BBH. The observed ZDIH is not a single value but varied between 4.48 and 4.60 km while the BBH also varied from 4.16 to 4.48 km for each rainy event during the studied period. The difference between the mean values of the ZDIH and BBH is about 320 km which is in agreement with previous researches conducted in the tropical zones.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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