A Priliminary Study on Radar Bright-band over Nyingchi Region in Tibet

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Introduction

The cloud and precipitation in the Tibet plateau has special microphysics characteristics that attract research attentions from global meteorological community. Weather radars in Tibet plateau play an increasingly important role in the microphysics and dynamic observation of cloud and precipitation. The existence of bright-band in radar echoes limits the performance of quantitative precipitation estimation (QPE), especially in high altitude area with complex terrain where melting layer is lower and occurrence of beam blockage happen heavily. In order to reduce the influence of the bright-band on the precipitation estimation, it is necessary to identify and correct the bright-band. This paper mainly analyze melting layer characteristics observed with the C-band Chinese New Generation Weather Radar (CINRAD-CD) and Ka-band all solid-state vertical profile radar in Nyingchi during the third Tibet Plateau atmospheric science field campaign in 2015.

Research Instruments

Figure 1. Positions of three devices (CD radar located in Biri mountain, in the lower right of the figure. Ka band all solid-state radar and radiosonde located in the Nyingchi meteorological bureau, in the upper left of the figure)

(a) (b)

Figure 2. (a) Ka band all solid-state radar located in the Nyingchi meteorological bureau, (b) CD radar located in Biri mountain

Methods

The principle of identifying bright-band

Different types and locations of precipitation correspond to different bright-band height. However, it usually appears in this height, below hundreds meters of 0°C isotherm.

The figure 3. shows bright-band's the conceptual mode of average vertical profile of reflectivity. The concept of average reflectivity is, within the range of selected elevation and azimuth, the average value of all range bins' reflectivity except for invalid value.

- Zmax: represents the maximum of average reflectivity;
- hmax: represents the height of Zmax;
- ht represents the height of 0°C isotherm (top height of bright-band);
- hb represents the bottom of bright-band.

Z(k) always decreases when it goes up to ht or goes down to hb along with the Zmax below hundreds meters of ht.

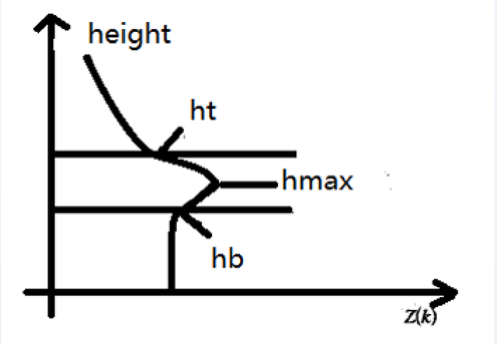

Figure 3.The vertical profile of average reflectivity diagrammatic sketch of bright-band

Identification algorithm of bright-band is as follows:

(1) The calculating of $\overline{Z}(h)$ in the same height

According to range bin's height of reflectivity, the definition of height in every layer is as follows:

$$H(h) = h \times \Delta h, \quad h = 2, \ldots\ldots N \qquad (1)$$

In the formula, h is the number of layer of 100m. N is the layers of vertical direction. The maximum of N in this paper is 150 (this means the maximum detection range is 150km).

The definition of $\overline{Z}(h)$ is:

$$\overline{Z}(h)=\frac{1}{M}\sum_{i=1}^{N_{ele}}\sum_{j=1}^{N_{rad}}\sum_{k=1}^{N_{rb}} Z(i,j,k), \ h=2,\ldots\ldots N \qquad (2)$$

- $\overline{Z}(h)$ is the average reflectivity at the h layer;
- Z(i,j,k) is the value of reflectivity at h layer, where reflectivity is greater than a certain threshold T_{dBZ};
- M is the number at h where reflectivity is greater than threshold T_{dBZ};
- N_{ele} is the number of elevation layers including by volume scanning;
- N_{rad} is the radial number including in one elevation;
- N_{rb} is the number of range bin including in a radial.

calculate $\overline{Z}(h)$ by all 9 layer elevations (N_{ele}=9) of whole volume scanning and all reflectivity data of range bin at 360 radials (N_{rad}=360).

(2) Identifications of bright-band

Find out the height of $\overline{Z}(h)$, h_{max}, the height of threshold T upward h_t and the height of threshold T downward h_b. If meet the conditions in formula (3), then admit that there is bright-band.

$$\begin{cases} h_t - h_b \geq D_1 \\ h_t - h_{max} \leq D_2 \\ h_{max} - h_b \leq D_2 \\ h_t - h_b \leq D_3 \end{cases} \qquad (3)$$

According to the analysis of precipitation progress in Nyingchi radar from Jul 2015 to Aug 2015, the identification results of bright-band can be better if these thresholds are as follows: T_{dBZ}=10dBZ, T=30%, D_1=200m, D_2=1000m, D_3=1500m.

Process design

Firstly, identify the location of the bright-band by the CD radar and Ka band all solid-state weather radar data; Then, analyze the position of bright-band corresponding relationship with the height of 0°C isotherm. The process of using CD radar to identify the bright-band is as follows: firstly, the reflectivity information is extracted from the volume scan data. Then, process of reflectivity data in vertical direction and draw the vertical profile of reflectivity according to the condition of the radar block. In particular, when data is blocked in some orientation, this orientation has no effective reflectivity. Consequently, the reflectivity at this position is not involved in calculating $\overline{Z}(h)$ at this height, that is to say, the Z(i,j,k) in the formula (3) only represents the reflectivity of none blockage position at a certain height. Finally, according to the judgment condition of (3) formula, obtain the information about bright - band (the bottom, top, peak and thickness of bright-band) and draw it.

Because Ka-band radar works in the scanning mode of vertical pointing, select the corresponding radial data at the same time and do the attenuation correction, and the position of bright-band can be identified according to the judging condition from format (3). The height of 0°C layer corresponding to sounding data can be read from the file of sounding data.

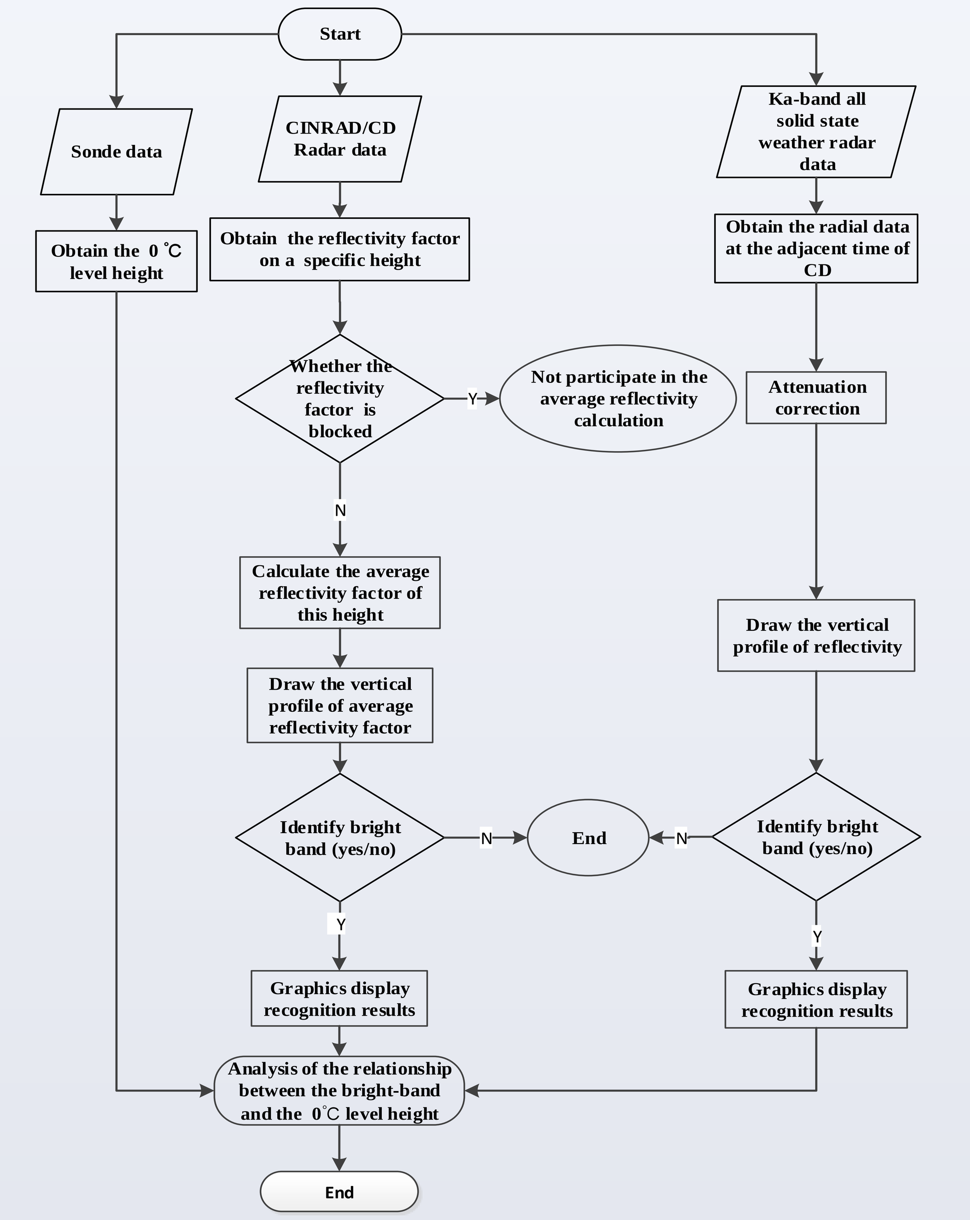

Figure 4 Process design and analysis of bright-band identification

Attenuation correction to echoes

When there are much steam and liquid water on transmitting path of millimeter-wave radar, it is necessary to do the attenuation correction to echoes. Adapts the method of bin-by-bin correction: do the attenuation correction to range bin in sequence to the radial direction of far from radar with the order of i=1, 2, 3…. After finishing the correction of attenuation to range bin i, τ_i can be calculated according to the result of the ith rang bin. Then τ_i prepares for the correction of the (i+1)th range bin. The result of attenuation correction with bin-by-bin can be get from formula (4) :

$$Z_r(i) = [Z_m(i)/\tau_{i-1}]\exp\{aZ_m^b(i)\Delta R\} \qquad (4)$$

The method classifies echo reflectivity into five levels cloud sector. Different levels adapt different attenuation correction coefficient a and b. The basis of classification is shown in table 1.

Table 1 Bases for classification

cloud type	reflectivity range
weak cloud area	Z＜-20dBZ
thick cloud area	-20 dBZ≤Z＜0 dBZ
cloud contains liquid water	0 dBZ≤Z＜15 dBZ
weak precipitation	15 dBZ≤Z＜25 dBZ
significant precipitation	Z＞25 dBZ

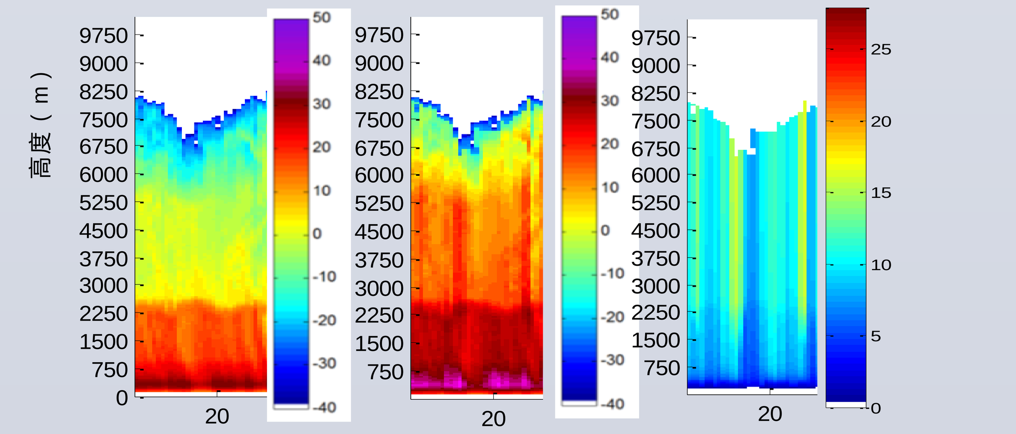

Figure 5 correct attenuation for Ka-band radar, the abscissa represents the time distance from the scan begins, elementary unit is "min". The elementary unit of reflectivity is "dBZ". The left figure is original reflectivity. The middle figure is reflectivity after corrected. The right figure is the value of correction.

Results of identification and analysis

According to the data of CD radar in Nyingchi on Aug 17, 2015, 13:10, select the 55th radial data of Ka radar on Aug 17, 2015 at the time of 12:00~13:30 to calculate the bright-band. The results are shown below：

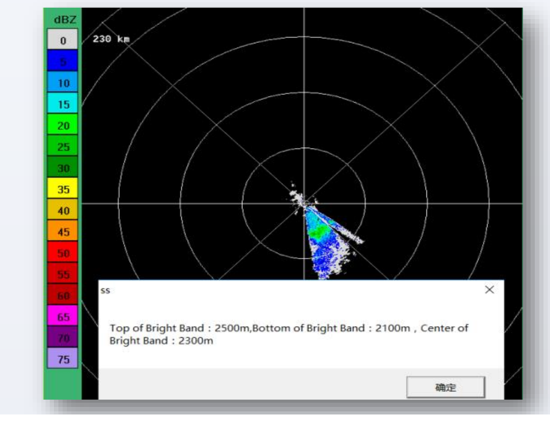

Figure 6 result of bright-band identification at 2015.8.17 13:10 (CD radar, background is the reflectivity of 6° elevation)

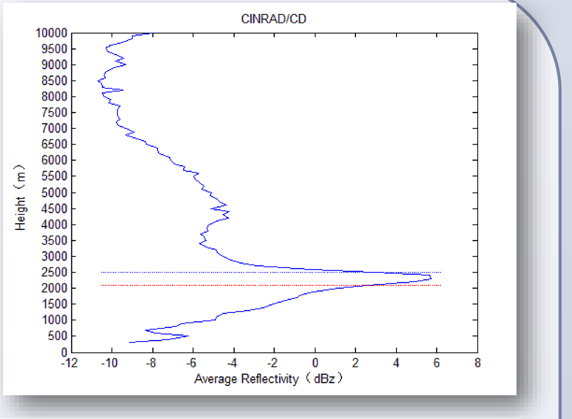

Figure7 VPR at 2015.8.17 13:10 (CD Radar),blue dash means top height of bright-band, red dash means bottom height of bright-band

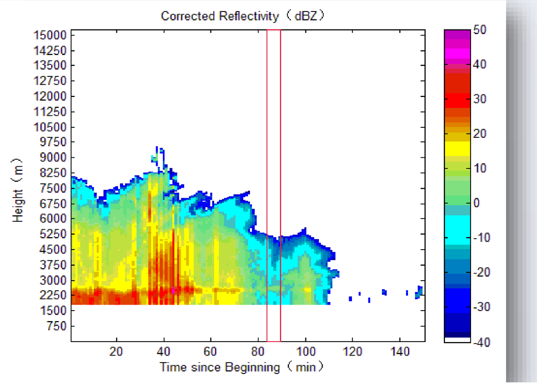

Figure 8 reflectivity after correction (Ka radar) at 2015.8.17 12：00~13：30

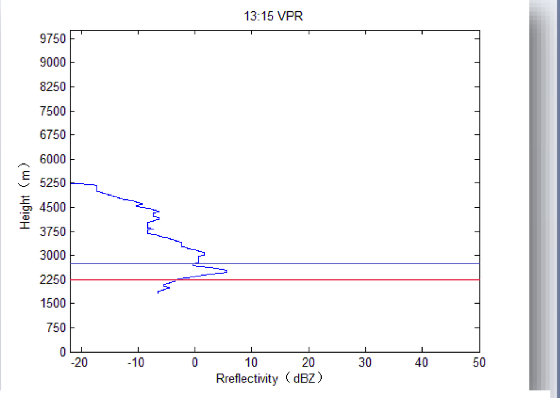

Figure 9 vertical Profile of reflectivity (Ka radar) at 2015.8.17 13：15

Due to the affection of ground clutter, the data of first 60 range bins in Ka-band radar are dropped out to identify bright-band (the length of range bin is 30m, 60 range bins represent 1800m).

Read the height of 0°C layer on Aug 17, 2015 from radiosonde file, the nearest time is 13:15, the 0°C appears at the altitude of 5732m.

Table 2 Zero-layer information of radiosonde

Zero-layer				
Air pressure	Height	Humidity	Dew point	T-Td
510	5732	89	−1. 5	1. 5

Table 3 gives the he identification and comparison results for bright-band, 8 times stratiform cloud precipitation during Jul, 2015 to Aug, 2015 in Nyingchi.

There are 4 times recognizing the bright-band. With the same judging condition, the top height, the bottom height and the peak height of the bright-band, recognized by CD radar are 115.5m, 108m and 74m average higher than Ka radar. The average peak height of bright-band recognized by CD radar is 82m below the height of 0°C layer. While the peak height of bright-band recognized by Ka radar is 156m below the height of 0°C layer.

Table 3 The identification and comparison results for bright-band, 8 times precipitation during Jul, 2015 to Aug, 2015 in Nyingchi.

Time	identified the bright-band (Yes/No)	Top / bottom / peak height of CD radar (m)	Top / bottom / peak height of Ka radar (m)	height of 0°C layer from sonde (m)	Top / bottom / peak height difference between the results of CD and ka radar （m）	peak height difference between CD radar and the height of 0°C layer （m）
8.19/19：10	Yes	5480/4780/5280	5342/4762/5173	5432	138/18/107	152
8.17/13：10	Yes	5880/5480/5680	5782/5342/5617	5732	98/138/63	52
8.17/19：10	No	--/--/--	--/--/--	5682	--/--/--	--
8.07/07：10	Yes	5480/5080/5180	5342/4892/5117	5222	138/188/63	42
8.07/13：10	Yes	5480/5080/5180	5392/4992/5117	5262	88/88/63	82
8.06/17：10	No	--/--/--	--/--/--	5562	--/--/--	--
7.21/07：10	No	--/--/--	--/--/--	5122	--/--/--	--
7.18/19：10	No	--/--/--	--/--/--	5242	--/--/--	--

Conclusions

Bright-band identification of the two kinds of radar are validated through temperature profile captured with radiosonde at the closest time in Nyingchi. Based on the observation data within a month, the following conclusions are drawn: (1)Two radars are able to consistently identify the bright-band.(2)The mean height of peak reflectivity value in bright-band is from ten meters to several hundred meters lower than the height of 0°C isotherms. (3)Different from other low altitude areas, the bright-band peak height of Nyingchi is more closer to the height of 0°C isotherm, and its thickness is smaller. (4)the vertical decline rate of reflectivity factor is larger in the bright-band range.