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Bright band height assignment with precipitation radar data based on multi-resolution analysis (MRA) of wavelet analysis

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Abstract

A method for reconstruction of cross-section of rainfall situations with precipitation radar data based on wavelet analysis of multi-resolution analysis (MRA) which allows extract a peak of the radar reflectivity is proposed in order to detect bright band height. It is found that the bright band height can be estimated by using the MRA with the basis of Daubechies wavelet family. It is also found that the boundaries in rainfall structure can be clearly extracted with MRA.

Keywords: Wavelet analysis; Bright band height; Precipitation radar; Multi-resolution analysis; Rainfall structure

1. Introduction

The bright band is a layer of enhanced radar reflectivity resulting from the difference in the dielectric factor ice and water and the aggregation of ice particles as they descend and melt. In accordance with Glickman (2000), the bright band height is the altitude of maximum radar reflectivity in the bright band. The layer over which the transformation from ice to water occurs defines the melting layer. The top of the melting layer is the melting level, also commonly accepted as the altitude of the 0 °C constant-temperature surface. By using Doppler radar data derived from the Doppler vertical velocity, bright band height is estimated using a negative relation between the Doppler vertical velocity and the bottom portion of the bright band where vertical gradients of radar reflectivity so that the bright band height can be estimated with the altitude at which the radar reflectivity shows its peak. White et al. (2002) proposed the method for bright band height detection algorithm by using the change rate of signal to noise ratio to the altitude and reflectivity profile for the purpose of monitoring the melting level forecasting.

One of the purposes of the precipitation radar is to estimate rainfall structure, vertical profile in particular. Radius or size parameter of raindrops can be estimated with precipitation radar data. The radar reflectivity profile can also be derived from the precipitation radar data. Then, the bright band height can also be assigned by looking at the peak of the radar reflectivity. There, however, are some peaks around the bright band height so that it is not so easy to find the most significant peak at which the bright band height is situated. On the other hand, signal to noise ratio is not so easy to estimate due to the fact that signal and noise discrimination is difficult. Then a new method which allows assign the bright band height derived from precipitation radar data is required.

The method proposed here is featuring the multi-resolution analysis (MRA) with the most appropriate base function of Daubechies wavelet family (Arai, 2001). Firstly, one-dimensional MRA is applied to the Tropical Rainfall Measuring Mission/Precipitation Radar (TRMM/PR) data along with the range direction.

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Furthermore, two-dimensional MRA is applied to the TRMM/PR data along with the range and scanning directions. Finally three-dimensional wavelet analysis of MRA is applied to the same TRMM/PR data along with the range and scanning directions as well as satellite track direction.

2. TRMM/PR and the preliminary experiment

2.1. TRMM/PR

The major specification of TRMM/PR is shown in Table 1. Major design and performance parameters are described by Kozu et al. (2001). The backscattering cross-section of raindrops can be estimated with the reference to the surface backscattering cross-section without rainfall (Meneghini et al., 2000). The bright band height is assigned by looking at the rain echo signal (Awaka et al., 1997). The radar reflectivity factor, Z with the rain attenuation correction for each radar beam is calculated based on the combining methods of Hitschfeld-Bordan and surface reference method (Iguchi et al., 2000). An illustrative view of the TRMM/PR data acquisition mechanism is shown in Fig. 1.

Table 1
The major specification of the TRMM/PR (precipitation radar onboard TRMM satellite)

Radar type	Active phased array radar
Frequency	13.796 and 13.802 GHz
Swath width	215 km
Observed range	From the ground surface to a height ≧15 km
Range resolution	250 m
Horizontal resolution	4.3 km
Sensitivity	S/N per pulse ≧0 dB for 0.7 mm/h rain at the rain top

2.2. The proposed method and the preliminary experiment

The aforementioned Z-factor which represents radar reflectivity as well as rain rate are derived from the TRMM/PR data. The bright band height is situated at the peak of the radar reflectivity. It, however, is not always that the bright band height corresponds to the height at which the Z-factor shows the peak. Also, it is not so easy to assign the bright band height because it is varied by location by location. Other than these, it is difficult to detect the peak of the radar reflectivity from the acquired noisy and gradually changed Z-factor in time. An example of the acquired Z-factor is shown in Fig. 2(a). In Fig. 2(a), there is the peak at around the range bin No. 73 and the leading edge is started from the range bin No. 70 and ended at around No. 75 so that the bright band height is situated around at the range bin No. 73 in this case. In order to identify the peak more clearly, the proposed method utilizes MRA with the most appropriate base function. The original signal is decomposed to two different wavelet frequency components, high and low through MRA analysis. If the low component is filled with zero, after that an original resolution of image is reconstructed with the high and the zero filled low components, the edge in the original image is sharply enhanced as is shown in Fig. 2(b).

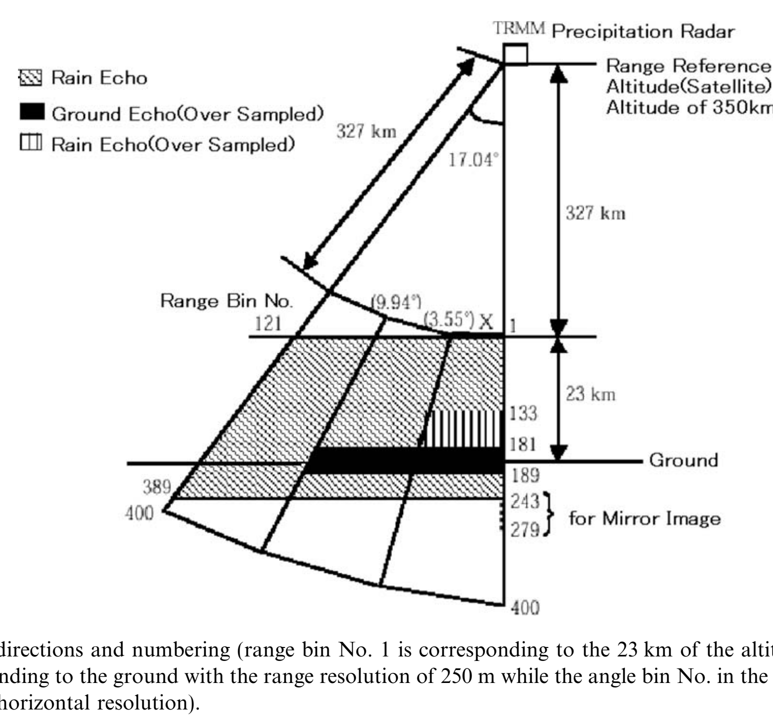

Fig. 1. Range and scanning directions and numbering (range bin No. 1 is corresponding to the 23 km of the altitude from the sea level while the range bin No. 140 is corresponding to the ground with the range resolution of 250 m while the angle bin No. in the scanning direction ranges from 0 to 49 with the 4.3 km of the horizontal resolution).