Investigation of Melting Layer for Convective Rain in Tropical Region

Feng Yuan, Yee Hui Lee, Shilpa Manandhar
School of Electrical and Electronic Engineering
Nanyang Technological University
50 Nanyang Avenue, Singapore 639798, Singapore
yuan0053@e.ntu.edu.sg, eyhlee@ntu.edu.sg

Yu Song Meng
National Metrology Centre
Agency for Science, Technology and Research (A*STAR)
1 Science Park Drive, Singapore 118221, Singapore
ysmeng@ieee.org, meng_yusong@nmc.a-star.edu.sg

***Abstract*—Convective rain occurs quite often in tropical region, however, very little is known of the melting layer for convective rain. In this paper, the S band dual-polarization radar data are processed to identify the convective rain melting layer in the tropical country of Singapore. By studying and isolating the convective rain region, it is found out that among the three radar measurements of reflectivity, differential reflectivity, and cross-correlation coefficient, the cross-correlation coefficient parameter is the most suitable indicator for convective rain melting layer detection. The reflectivity can be used to differentiate between stratiform rain and convective rain.**

Keywords—Melting layer, dual-polarization radar, convective rain.

I. INTRODUCTION

The melting layer is the region where the solid precipitation transits to liquid precipitation. The top boundary of melting layer is also called the melting level. At this region, the reflectivity generally increases and causes a bright band effect in the radar measurements. To study the characteristics of melting layer is very important for accurate estimation of rainfall and microphysical characterization of the cloud [1].

The melting layer can cause transmitting signal to suffer from both attenuation and scattering effects. It is important to study the melting layer for remote sensing and satellite-to-earth communications applications [2-3]. Reported in [4], the melting layer can contribute significantly to the overall path attenuation during the periods of stratiform rain and for the slant path with low elevation angles.

In this paper, convective rain melting layer is detected and analyzed by using S band dual-polarization radar in Singapore. As a tropical country, there are more frequent convective precipitations compared to the subtropical and temperate region. The properties of melting layer from stratiform rain are extensively [1-3] studied in temperature region. However, very limited information [5] is reported about convective rain. Therefore, in this paper, the melting layer for convective rain will be investigated and discussed.

II. DATA DESCRIPTION

S band dual-polarization weather radar measurements are processed to identify melting layer. The radar is operating at a frequency of 2.71 GHz located at Changi airport (1.35ºN, 103.97ºE). Every 5 minutes, it performs a full volume scan with 8 elevation angles (1˚, 1.5˚, 3˚, 5˚, 7.5˚, 10˚, 20˚, and 40˚). The radial resolution is 250 m and the maximum range of the radar is 120 km.

In order to get a relatively good vertical resolution and large coverage area, the radar measurements with elevation angle of 5˚ are chosen to identify and analyze the melting layer. Three measurements [1, 6] provided by dual-polarization radar are processed and used to identify melting layers in stratiform and convective rain regions. They are, the reflectivity (Z), the differential reflectivity (Z_{DR}), and the cross-correlation coefficient (ρ_{HV}).

III. RESULTS AND ANALYSIS

One famous algorithm used for the detection of melting layer for stratiform rain is presented in [1]: in a vertical window of 500 m, the three measurements from radar should fulfill the following criteria, ρ_{HV} falls between 0.9 and 0.97, the maximum value of Z is within range from 30 dBZ to 47 dBZ and the maximum value of Z_{DR} is within range from 0.8 dB to 2.5 dB.

A. Melting Layer Detection

To identify and analyze melting layer in tropical region, one event with occurrence of both stratiform and convective rain is found and processed. The PPI (Plan Position Indicator) images of ρ_{HV} from radar data with elevation angle of 5˚ are plotted in Fig.1.

The center of the figure is Changi airport of Singapore. In order to clearly show the melting layer, the range of color bar is adjusted to be in the range of [0.7 1.1]. If the value of ρ_{HV} is smaller than 0.7, it represents non-meteorological data which can be neglected [6]. By adapting the criteria in [1], a light circle ring can clearly be observed at height around 4 km within ρ_{HV} range of 0.9 to 0.97 in Fig. 1, which indicates the height and thickness of melting layer.

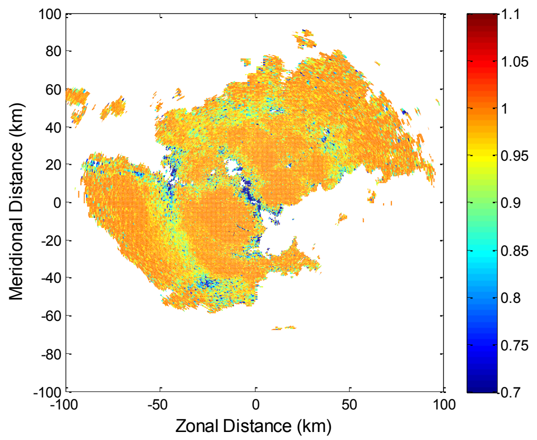

Fig. 1. Dual-polarization radar measurement PPI images of ρ_{HV} at 06:00 UTC on 21st April 2014.

B. Identification of Melting Layer for Convective Rain Region

It is difficult to differentiate between the stratiform rain and convective rain region by only using ρ_{HV} data, therefore the radar reflectivity Z is plotted in Fig. 2. Taking north as azimuth angle of 0°, radar reflectivity is mapped on the height-azimuth plane, which can give a clear separation between stratiform rain and convective rain. After checking the reflectivity at different heights, stratiform rain is observed as the azimuth angle within [180˚, 290˚], and for convective rain the range of azimuth angle is combining [1˚, 30˚] and [310˚, 360˚]. It can easily be observed that the bright band in stratiform rain is around 4 km to 5 km; while the high reflectivity from convective rain has a large vertical extension due to large raindrop size and fast falling velocity, therefore there is no clear bright band for convective rain.

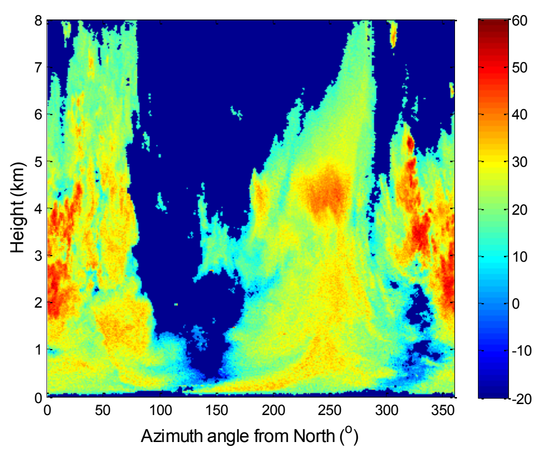

Fig. 2. Radar reflectivity at 06:00 UTC on 21st April 2014 mapped on the height–azimuth plane.

C. Characteristics of Convective Rain Melting Layer

After splitting the stratiform and convective rain events, the slant path averaging value of ρ_{HV}, Z and Z_{DR} for convective rain region are plotted in Fig. 3. The vertical line in subplot of ρ_{HV} represents the value of 0.97. In Fig. 3, it can be seen that for the first subplot of ρ_{HV}, the melting layer height and thickness can be identified by using criteria ρ_{HV} < 0.97. However, different from stratiform rain melting layer stated in [1], both Z and Z_{DR} have two peaks, and both of them reach a maximum height of around 2 km, which is not the valid melting layer height in the tropical region.

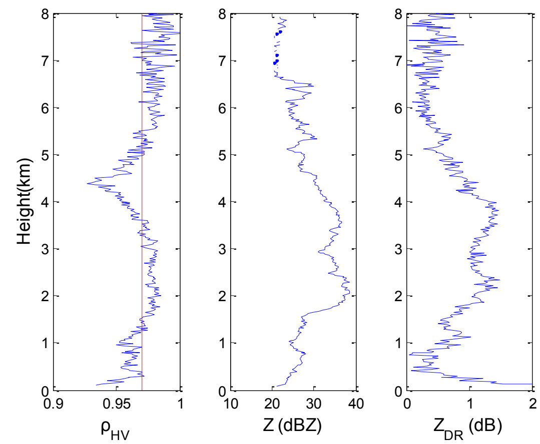

Fig. 3. Averaging slant path of ρ_{HV}, Z and Z_{DR} for convective rain at 06:00 UTC on 21st April 2014.

IV. Conclusion

In this paper, one rain event with convective rain melting layer is investigated in the tropical region and studied by using the S-band dual-polarization weather radar data.

Among the three measurements, the cross-correlation coefficient ρ_{HV} can indicate the melting layer height for convective rain events. The maximum value and the variation of reflectivity Z are shown to be useful to differentiate convective rain events but not useful for detecting melting layer in convective rain region.

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