Identification of Snow from GPM-DPR observations and cross validation with S-Band Ground Radar dual polarization measurements

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***Abstract*—The Global Precipitation Measurement (GPM) mission Core Observatory is equipped with a dual-frequency precipitation radar (DPR) operating at frequency channel of 13.6 GHz (Ku-band) and 35.5 GHz (Ka-band). In this paper, GPM-DPR's simultaneous observations at these two frequencies are used to study the characteristics of vertical profile of reflectivity of snow. An algorithm to identify falling snow is considered. Its performance is also evaluated by cross validation with dual polarization measurements from ground radar.**

I. Introduction

At mid and high latitudes, snow, as well as light rain contribute for a significant fraction of global precipitation. In fact, above 60^{O} latitudes liquid precipitation is dominated by snowfall. It should be noted that areas around the globe where snowfall is predominant are remote which makes it difficult to be monitored by ground instruments. The Global Precipitation Mission (GPM) satellite is capable of providing high-resolution, three dimensional data on precipitation over a wide range of latitude (65^{O}N – 65^{O}S) [1]. Thus, it can be used to study snowfall. It is also quite advantageous to have independent measurements at two frequencies since the resulting difference in attenuation at both the frequencies enables the satellite to retrieve more accurate information on particle size distribution. Non-Rayleigh scattering effect occurring at Ka-band also extends GPM's capabilities on having a higher detection sensitivity for falling snow.

II. Identification of snow

A. Overview

Dual-frequency ratio observations have been used to perform melting layer detection and rain type classification [2]. This has been implemented in the Profile Classification Module of the current DPR level 2 algorithm [3]. Based on this, in this paper, we focus on enhancing the dual frequency classification method. An algorithm to detect snow falling on the ground is considered which is expected to perform effective separation between rain and snow using dual-frequency ratio.

B. Implementation

The basis of the algorithm is to study and analyze the difference in measured DPR reflectivities at the two frequencies, a quantity often termed as measured dual-frequency ratio (DFRm) This can be defined as

$$DFRm = 10\log_{10}(Zm_{Ku}) - 10\log_{10}(Zm_{Ka}). \quad (1)$$

Here, Zm_{Ku} and Zm_{Ka} are the measured equivalent reflectivity factor in linear scale at Ku and Ka band respectively. The shape and slope of the DFRm vertical profiles are controlled by non-Rayleigh scattering and different path integrated attenuation at the two frequencies. After analyzing several DFRm vertical profiles it has been found that snow profiles have some typical features. They have very steep slopes with an absence of melting layer region. They also happen to have very low storm top heights and low Ku-band reflectivity generally below 30 dbZ. A typical snow profile with the above mentioned features is shown below from a GPM-DPR overpass on March 17th, 2014 over West Virginia, USA.

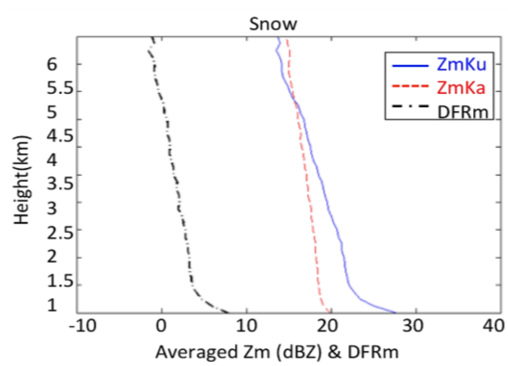


Fig. 1. Vertical profiles of snow at Ku and Ka band.

It can be observed that the storm top height extends till 6.5 km from the ground which is lower than typical convective or stratiform cases, which extends till 10 to 12 km in height. It is also interesting to observe that due to greater sensitivity, above 5 Km, reflectivity at Ka-band is higher than that at Ku-band and it gradually decreases at lower heights due to strong attenuation effects.

Based on these observations a parameter named as snow-index (SI) is defined as

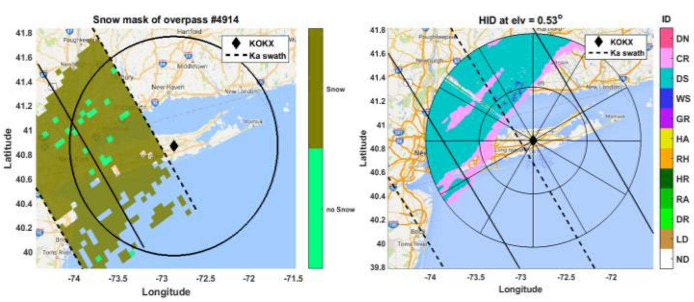
$$SI = \frac{mean(abs(DFRm_{slope}))}{Zm_{Ku}\_max \times Storm\_top\_height} \quad (2)$$

It is used in the snow mask algorithm being considered in this paper. The algorithm calculates SI for individual vertical profiles from GPM-DPR observations separately and checks for two criteria. The first is, the SI should be greater than a threshold value and second is, whether the zero-degree isotherm height for that profile is within 8 bins from the clutter free region. On passing both the criteria the vertical profile is flagged as snow. The algorithm will be presented.

III. Case Studies and Results

The performance of the snow mask algorithm is next evaluated by cross validation with S-Band ground radar dual polarization measurements. NEXRADs, operated by the National Weather Service (NWS) of USA, are chosen for this study. Two cases of GPM-DPR overpass with ground radar sites have been selected with sufficient amount of precipitation data overlapping DPR Ku, Ka swaths and falling within 100 Km ground radar range. Hydrometeor classification [4] is performed on NEXRAD data and cross compared with the snow product. Both the cases are shown below.

A. GPM-DPR Overpass (#4914) with KOKX located at Upton, NY, USA on Jan 9th, 2015 at 12:24 UTC

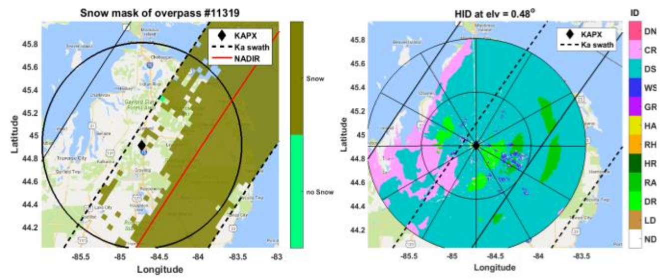


(a) (b)

Fig. 2. (a) GPM-DPR snow mask for overpass #4914. (b) NEXRAD KOKX hydroclass product.

In the above figure, snow mask product is shown on the left while ground radar hydroclass at an elevation of 0.5^{O} is shown on the right. It should be noted that the lowest elevation scan available from NEXRADs has been used. The outer black circle indicates 100 Km range radius of the radar. The dotted line indicates GPM Ka swath. Considering the left image, the olive green color indicates DPR snow product while the light green color shows no snow. On the right image, the blue color indicates dry snow from hydroclass product. Occasional light pink color shows presence of crystals. Here, we are focusing on the common observation region between the GPM Ka swath and 100 Km radar range. It can be observed that on both the images, the common region of interest shows snow.

B. GPM-DPR Overpass (#11319) with KAPX located at Gaylord, MI, USA on Feb 25th, 2016 at 04:06 UTC



(a) (b)

Fig. 3. (a) GPM-DPR snow mask for overpass #11319. (b) NEXRAD KAPX hydroclass product.

In the above figure some portions of light green color can be seen on the right image which indicates drizzle. This is due to the hydroclass algorithm's [4] clustering technique for improving noisy data. Compared to the right image, some missing data can be observed within the Ka swath of the left image. This can be accounted for reflectivities falling below the minimum detection threshold of DPR. Overall, it can be concluded the comparison show good agreement.

IV. Summary

Vertical profiles of snow has been studied and a falling snow on ground detection algorithm is successfully implemented. The algorithm is presented and discussed. The snow product is next compared against ground based observations. Several snow events from GPM-DPR overpass with NEXRAD sites have been studied from which two such cases are presented. As an initial evaluation method, the studies show convincing results. Further evaluation, such as comparison with passive radiometer products, is necessary. More GPM-DPR overpasses will be routinely studied for further improvement and refinement of the algorithm.

Acknowledgement

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References

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