DROP SIZE DISTRIBUTION RETRIEVAL FROM RADAR DATA TO ENHANCE THE SPECTRAL BIN CLASSIFICATION IN DETECTING ICING CONDITIONS

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1. INTRODUCTION

The impacts of winter weather on air travel are well known, and despite greater forecast accuracy, safety and productivity are still at risk. Winter weather causes hundreds of airline delays every year, and flying through areas of supercooled liquid can be very dangerous. From 1978-2005, the NTSB recorded 645 aircraft accidents and incidents in the United States alone due to icing. There were an additional 299 icing-related incidents recorded in the NASA Aviation Safety Reporting System during the period. Improved forecasts of the location and height of supercooled drops can help air traffic avoid regions where hazardous icing is likely, and therefore protect lives and increase efficiency.

Current methods of determining the precipitation phase at the surface and aloft, such as the NEXRAD Hydrometeor Classification Algorithm (HCA), have serious limitations. This is because only one class can be assigned for each resolution volume, and this classification is dominated by radar signatures, which may not be the main component in the water fraction. In addition, this algorithm only allows for one melting/freezing level, and partial melting/freezing processes are not considered. It is therefore inadequate for determining the phase of precipitation aloft and at the surface in complex winter weather regimes.

2. THE SPECTRAL BIN HYDROMETEOR CLASSIFICATION ALGORITHM

2.1 The Algorithm

The Spectral Bin Hydrometeor Classification Algorithm (SBC) has been developed by the Cooperative Institute for Mesoscale Meteorological Studies (CIMMS) with the goal of improving precipitation phase discrimination throughout an atmospheric profile. The SBC is an algorithm which classifies the phase of particles depending on the atmospheric profile. Particles are grouped into different size "bins" and the microphysics scheme is run for each bin through the full vertical column. The SBC approximates the surface precipitation classification by examining the fraction of particle phases at the surface. This fraction depends on an assumed particle-size distribution.

2.2 Data Used to Run the Algorithm

In order to run the SBC, three datasets are used. The first is the High-Resolution Rapid Refresh (HRRR) weather model, which is run hourly over the Continental United States by the National

Centers for Environmental Prediction (NCEP). Vertical profiles of temperature, humidity, and geopotential height are used as input to the SBC.

3. IMPROVEMENTS TO THE SBC

3.1 Drop Size Distribution

To improve the performance of the SBC, modifications have been made to allow the drop size distribution (DSD) in the algorithm to vary depending on measured radar reflectivity (Z_H). These changes should improve the algorithm's performance because larger radar reflectivity (Z_H) generally indicates larger particles. Smaller drops melt and freeze much faster than larger drops, which results in changes of precipitation phase versus a single, universal DSD. The number concentration of drops in different size bins can significantly change the liquid water fraction (LWF) diagnosed by the SBC.

The SBC has been modified to use a form of the Marshall-Palmer (M-P) DSD, and then tested on several winter storm events during the past 10 years. The M-P method changes the number and size of drops based on radar reflectivity (Z_H). This avoids retrieval error from Z_{DR} bias and is also computationally efficient. The M-P method was modified by diagnosing the intercept parameter (N_0) to allow for higher numbers of small drops for low Z_H cases, and fewer small drops when Z_H is large. This is accomplished in part through the application of a Z_H threshold, which roughly separates drizzle cases from heavier precipitation cases, and was set at 10 dBZ through an analysis of observations.

The M-P DSD uses Z_H data from the Multi-Radar/Multi Sensor Reflectivity At the Lowest Altitude (RALA; Zhang et al. 2016) gridded dataset. This dataset is chosen because it is able to capture Z_H values from the lowest constant-height surface available, and quality control procedures have already been applied.

3.2 Vertical Super-sampling

Additional changes to the SBC include the implementation of vertical super-sampling to improve detection of shallow freezing and melting layers. The algorithm continues to use the native model resolution of 25 hPA, but super-samples layers that have a 0 C cross to more accurately depict transition zones aloft. It is unreasonable to change immediately from snow to rain without at least a thin transition zone between the cold and warm layers. Dynamic super-sampling will help to address this issue.

4. RESULTS

4.1 A Case Study from KPIT

In order to determine any changes in accuracy of the SBC using the new M-P method, the SBC is run at point locations using launched soundings, and the surface hydrometeor phase is validated against the nearest Augmented Surface Observation Station (ASOS) report.

For this case study, the winter weather event on 9 Feb 2017 is analyzed using the 12 UTC launched sounding from KIAD near the Dulles Airport. This sounding was used to run the SBC over the sounding site location. The ASOS observation at this time at KPIT is of a rain/snow mix (RASN).

The SBC is first run using the original universal DSD, and then using the new M-P DSD. The M-P DSD Z_H value is obtained by calculating the average value of RALA over the surrounding 5 km grid relative to the sounding location.

Original Method (Universal DSD)
Surface Class: Rain

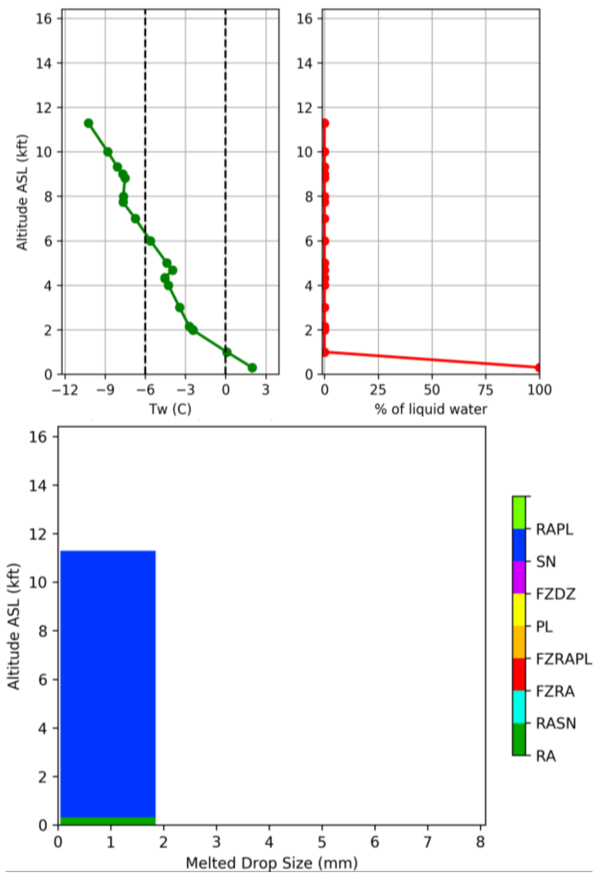

Figure 1: Vertical profile of wetbulb temperature (TW) and liquid water fraction (top), and vertical profile of hydrometeor phase with respect to particle diameter (bottom).

New Method (M-P DSD)
Surface Class: Rain/Snow Mix

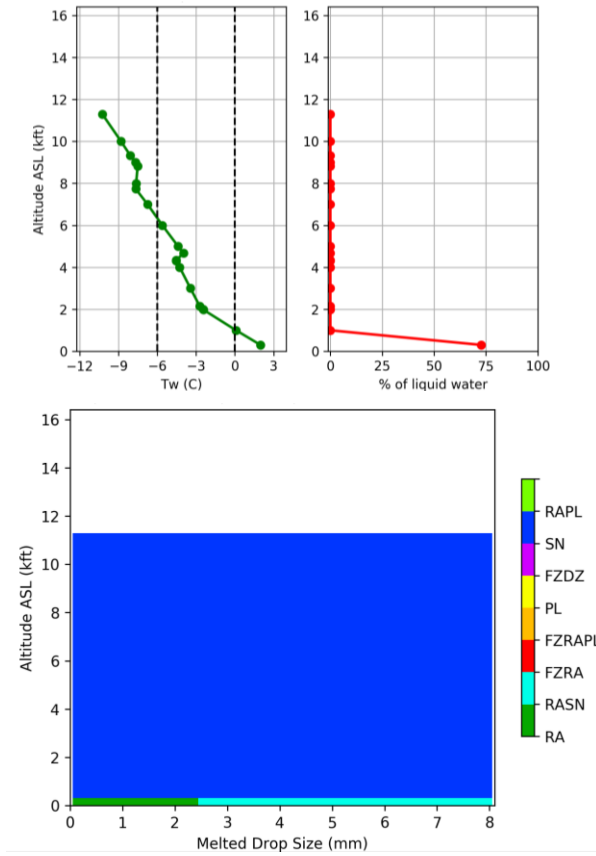

Figure 2: Vertical profile of wetbulb temperature (TW) and liquid water fraction (top), and vertical profile of hydrometeor phase with respect to particle diameter (bottom).

Using the new M-P DSD corrects the surface classification error by allowing larger particles to exist in the volume. These larger particles take a longer amount of time to melt than smaller particles, and therefore some remain frozen even at the surface. This results in a correct classification of RASN at the surface using the new method.

4.2 A Case Study Using the HRRR Model

In order to gain an area-based interpretation of surface classification changes, several case studies are run using HRRR model soundings for past winter storm events. ASOS reports are used as verification. The event shown below is valid for 12UTC on February 12th, 2019.

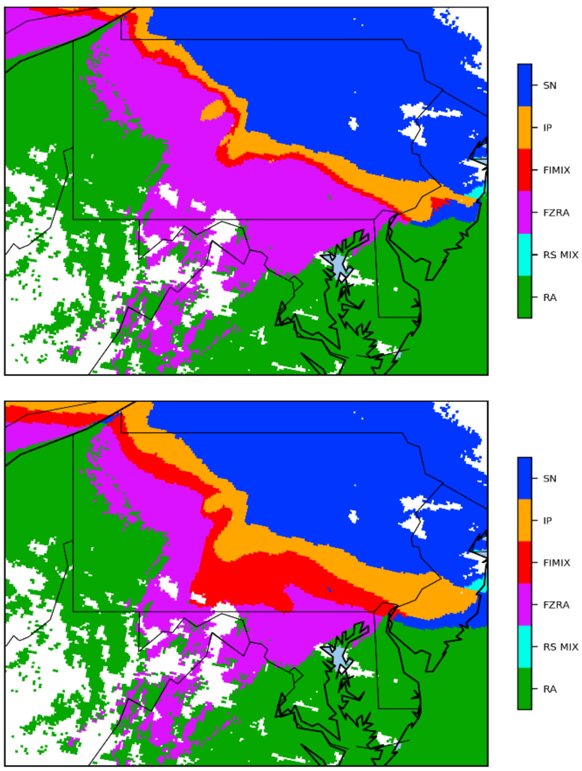

Figure 3: The surface precipitation classification using the original method (top) and the new method (bottom).

This winter storm resulted in significant impacts to the Dulles, Philadelphia, Harrisburg, and Newark airports, among others. Dulles reported ice pellets before transitioning to freezing rain, Philadelphia reported ice pellets, Harrisburg reported ice pellets, and Newark reported snow.

A comparison of the figures shows that the new method produces a much wider mixed-phase region, in particular the freezing rain ice pellet mix (FIMIX) region. According to the limited verification data available, the new method reproduces the observed precipitation phase more closely than the original method.

4.3 Verification Against ASOS Observations

In order to statistically determine whether the new method is performing more accurately, the SBC is run at point locations using observed sounding data. The surface precipitation classification is verified based on nearby ASOS reports.

This procedure is still in progress, but initial comparison for rain and RASN are both improved by approximately 5% using a dataset of 30 events over the past four years. Additional cases are being accumulated, and the exact DSD method is still being adjusted.

5. PRELIMINARY CONCLUSIONS

Classification accuracy is improved using the M-P DSD, but results are not yet finalized. In several cases analyzed, larger particles are allowed using the M-P method than in the universal DSD because measured Z_H was relatively high. Larger particles take more time to melt than smaller particles, which allows for a correct diagnosis of RASN below a shallow warm layer, whereas the original method only diagnoses rain. Similarly, some events with very low Z_H values, such as drizzle events, are represented more accurately because the M-P DSD does not allow for large particles, whereas the universal DSD includes larger particles.

Adjusting the Z_H threshold, M-P DSD coefficients, and SBC precipitation type thresholds change the percent hit results significantly. Preliminary results are promising, and investigations will continue as needed to implement the modifications into an operational setting.

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