5.10 Development and testing of polarimetric radar applications in WDSS-II

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1. ABSTRACT

Polarimetric radar technology is expected to emerge into operational forecasting during the next few years. NSSL's Warning Decision Support System - Integrated Information (WDSS-II) is being used to develop and test polarimetric radar applications. These include fuzzy logic membership functions for automated hydrometeor classification, melting layer identification methods, and procedures for classification of surface precipitation type. WDSS-II also allows the integration of data from other systems, such as numerical model and surface observational data, to enhance algorithm performance. The design of these test and evaluation procedures is described. Implications for operational implementation are discussed.

2. INTRODUCTION

As shown during the Joint Polarization Experiment (JPOLE) (Schuur et al. 2003a), polarimetric radar technology applied to the operational WSR-88D network can be used to improve real-time forecasting. The new “base” products generated from a polarimetric radar can be used to produce accurate maps of hydrometeor type through the detection of scatterer shapes, sizes, and fall characteristics. Melting layer signatures are well-defined, further aiding in the mapping of hydrometeor types. Hydrometeor classification algorithms (HCAs) written for polarimetric radars use fuzzy logic to make classifications (Schuur et al. 2003b), due to some overlap in polarimetric radar characteristics between pairs of scatterer types. Numerical weather prediction (NWP) model output can be used to "clean up" the output from the HCA. Many users may benefit from a map of surface precipitation type. Lowest-altitude output of HCA can be used, along with NWP output and surface temperature data below the lowest radar data, to determine and map the likely surface precipitation type.

The HCA, using only fuzzy logic membership functions, is being prepared for deployment in future versions of the WSR-88D's Open Radar Product Generator (ORPG). The ORPG, however, is not designed to ingest and process information from other sources, such as NWP data and surface temperature observations. Polarimetric radar applications using these sources must be designed, tested, and evaluated outside of the ORPG framework. WDSS-II (Hondl 2002) is designed to efficiently ingest data from a variety of sources. With WDSS-II, applications using polarimetric radar data are not limited to using only the data from the radar itself, but can also call on NWP output and surface temperature data to enhance HCA output and produce a field of surface precipitation type.

3. SYSTEM DESIGN

Figure 1 describes the initial design of polarimetric radar applications in WDSS-II. As the “base” products from each radar elevation angle are received, a “bright-band” detection algorithm is first run. The algorithm, as described by Giangrande and Ryzhkov (2004), runs on elevation angles generally between 4 and 10 degrees. A stretch of gates along a radial with relatively high reflectivity and differential reflectivity, along with low correlation coefficient, is a typical indicator of the location of melting hydrometeors, marking the region just below the 0 ºC level. When a bright-band signature is not detected along a radial, a running average from surrounding radials, elevation angles, or recent volume scans can be used as a default value. If insufficient bright-band detections have been made, a default value of 0 ºC height from a nearby sounding can be used.

After the bright-band detection algorithm has completed its run, the hydrometeor classification algorithm (HCA) begins. The algorithm, as described in Schuur et al. (2003b), uses the polarimetric “base” products, as well as traditional reflectivity information, and two “texture” products – the standard deviation of reflectivity SD(Z) and the standard deviation of differential phase shift SD(ϕ_{DP}) – to classify hydrometeors using “fuzzy logic” membership functions. Radial velocity data are used to ensure that scatterers moving at greater than 1 ms^{-1} are not classified as ground clutter or anomalous propagation. In addition, the output from the bright-band detection algorithm is used to further discriminate between rain and snow.

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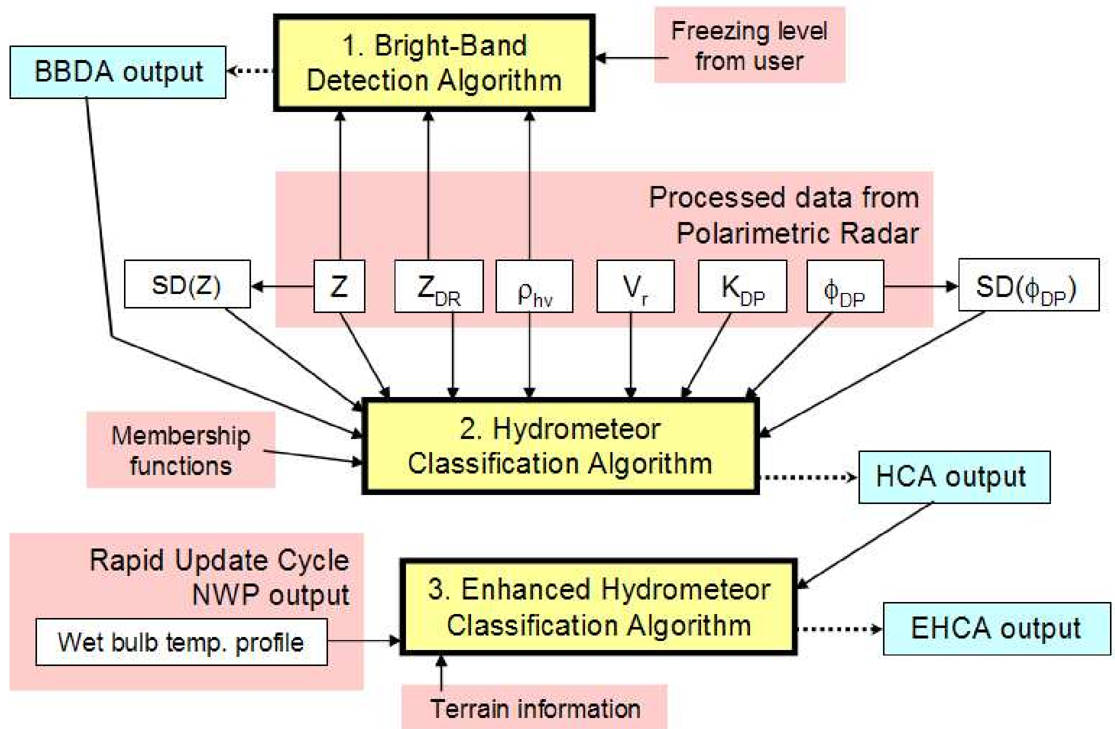

Figure 1. Chart describing polarimetric radar-based hydrometeor classification procedures in WDSS-II. Solid arrows denote inputs, and dashed arrows represent outputs.

Finally, after the HCA is received, the "enhanced" hydrometeor classification algorithm (EHCA) is run. As described by Scharfenberg and Lakshmanan (2004), the EHCA uses wet bulb temperature profile data from the Rapid Update Cycle model to further "clean up" the HCA output, particularly to aid in the discrimination between rain and snow. Very preliminary results suggest the HCA output using bright-band identification procedures generally produces reasonable results. Incorporation of numerical model information is often helpful during light precipitation events, when rain and snow

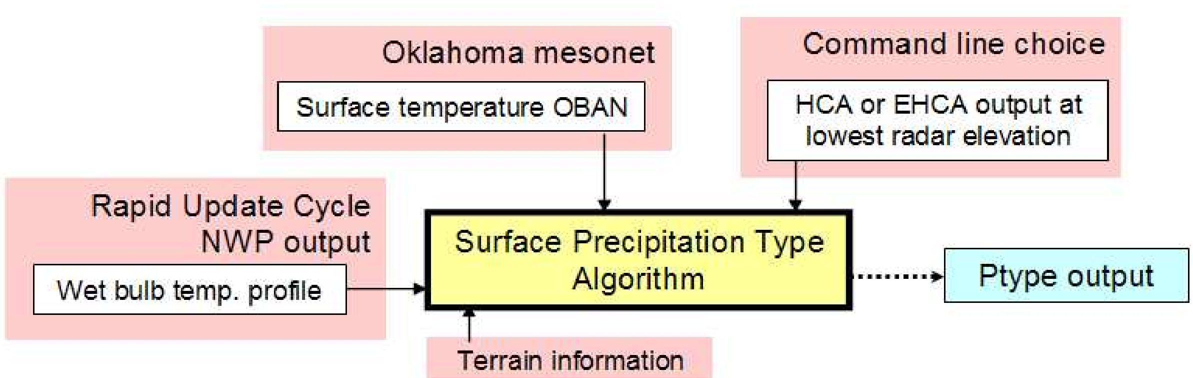

Figure 2. Chart describing the production of the polarimetric radar-based surface precipitation type field in WDSS-II. Solid arrows denote inputs, and dashed arrow represents output.

hydrometeors have similar polarimetric characteristics and bright-band signatures are ill-defined.

Figure 2 describes a separate algorithm in the WDSS-II polarimetric applications package. The “surface precipitation type algorithm” uses output from either the HCA or EHCA (as selected by the user at the command line) at the lowest elevation angle to determine whether precipitation is being detected. If snow is the dominant type in the HCA or EHCA, model wet bulb temperature data from below the lowest radar elevation angle, as well as temperature data from the Oklahoma Mesonet, are used to determine whether the snow is expected to melt before reaching the ground. In addition, surface temperature data are used to determine if liquid hydrometeors are expected to freeze on contact with the surface. These methods allow for a mapping of surface precipitation type using polarimetric radar as a starting point, and allow for explicit mapping of likely regions of freezing rain.

The HCA fuzzy logic membership functions are sometimes adjusted as new research data sets are examined, so the WDSS-II polarimetric applications package was designed with the ability to allow users to make quick changes to the membership functions. This was done by setting the membership functions in a stand-alone “adaptable parameter” file, outside the HCA code. This flexibility also allows rapid changes to the fuzzy logic as data are collected and evaluated in real-time.

4. PRELIMINARY RESULTS AND DISCUSSION

Each component of the WDSS-II polarimetric applications package has been tested individually on a few archived data sets. Work to integrate each component into an integrated package that can be run in real-time is ongoing. Figure 3 shows example output from the EHCA run on data collected during a major winter storm. This run included HCA output with bright-band identification, and the HCA output was “cleaned up” using numerical model thermodynamic output to yield the EHCA output shown. In this case, the output on 0.5 degree elevation-angle radar data depicts a melting level that slopes downward from south to north, which was also indicated in observational data. Figure 4 shows results from the surface precipitation type algorithm during the same event. Surface temperature data provided by the Oklahoma mesonet helped define areas where freezing rain was likely to be reported at the surface, and was well-associated with “ground truth” reports from spotters and the media.

The major benefit of applying numerical model and surface temperature data to polarimetric-radar-based applications is expected to be better discrimination of spatially and temporally diverse hydrometeor types during winter storms. Unforunately, only a few polarimetric radar winter storm cases are available at this time. As more data are collected, including real-time data from the National Severe Storms Laboratory's prototype polarimetric WSR-88D, the integrated package of polarimetric radar applications will be further tested and refined, along with each of its components.

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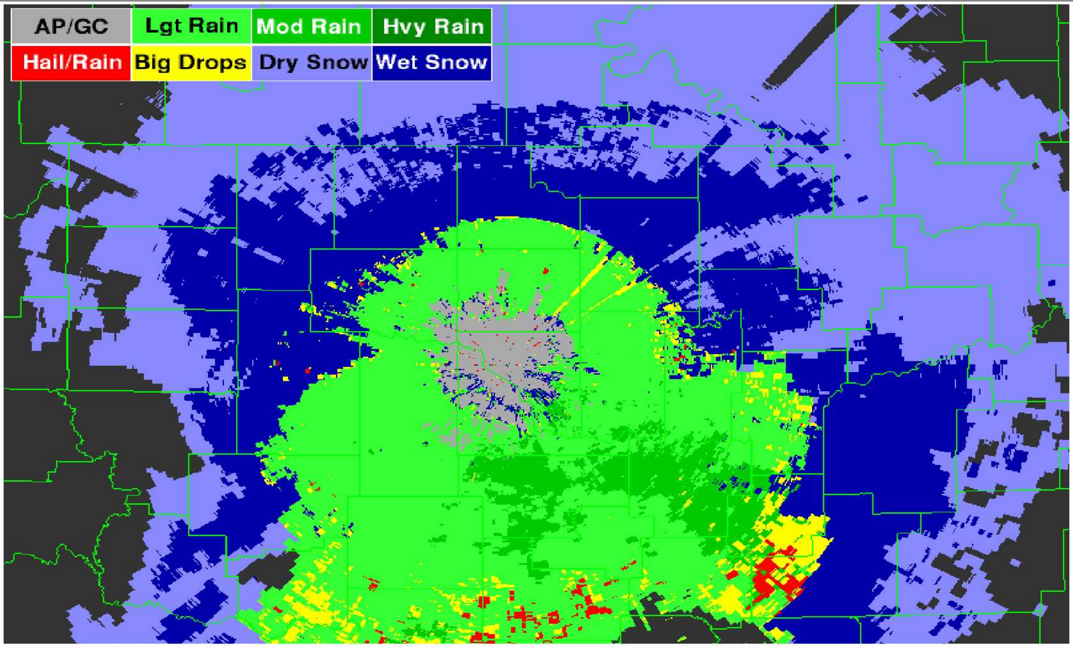

Figure 3. Output of polarimetric enhanced hydrometeor classification algorithm (EHCA) from data collected during a winter storm on 4 December 2002.

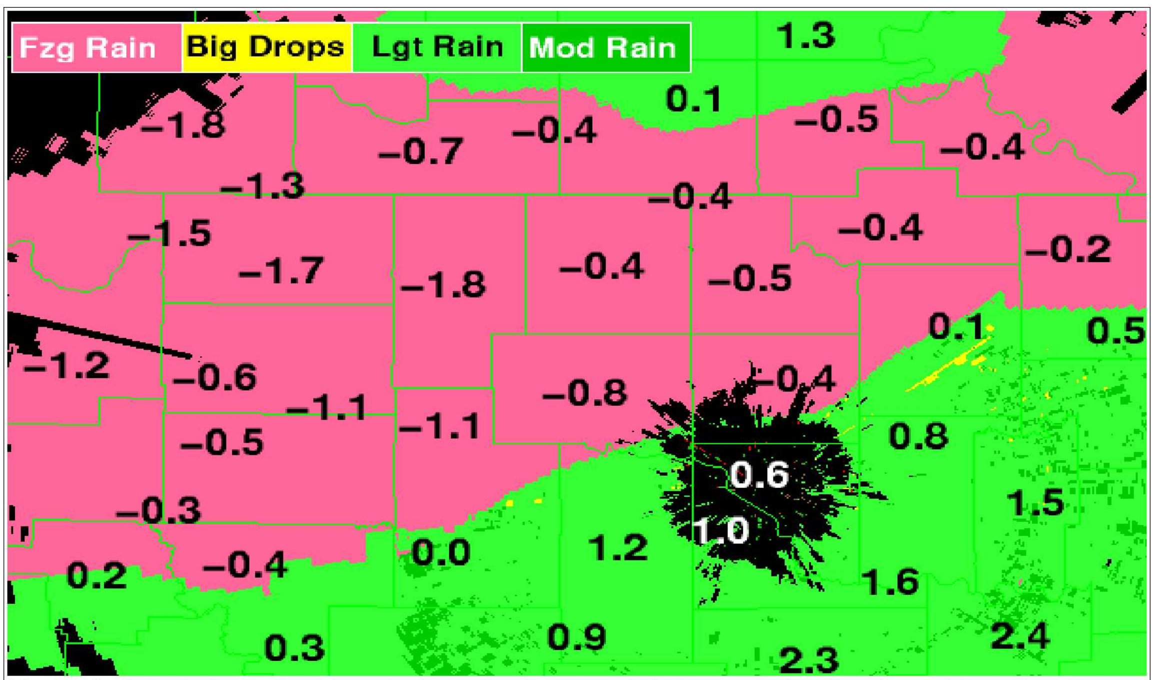

Figure 4. Output of polarimetric radar-based surface precipitation type algorithm from data collected during a winter storm on 4 December 2002. Plotted temperatures in degrees Celsius provided by the Oklahoma Mesonet.