P5.7 THE USE OF NWP DATA IN POLARIMETRIC HYDROMETEOR CLASSIFICATION

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1. ABSTRACT

Hydrometeor classification algorithms using polarimetric radar data have been found to provide reliable bulk hydrometeor information. Deliniation between light rain and light snow can also be aided by well-defined “bright band” signatures in the polarimetric fields. Such signatures, however, are not always present, and freezing rain at the surface cannot be detected with radar. Incorporating numerical weather prediction output and surface temperature observing networks can somewhat mitigate these limitations. Using the National Severe Storms Laboratory's (NSSL) Warning Decision Support System – Integrated Information (WDSS-II), enhancements were made to the polarimetric hydrometeor classification algorithm, and a new surface precipitation type field was developed. The new products were developed and tested using polarimetric radar data, Rapid Update Cycle model output, and data from the Oklahoma Mesonet collected during a major winter storm on 3-4 December 2002.

2. INTRODUCTION

Polarimetric radar technology is quickly emerging into operational meteorology. The network of WSR-88D radars in the United State1s is expected to be upgraded to include polarimetric capabilities during the next several years. Polarimetric radar data allow the classification of scatterer types through fuzzy logic algorithms (Zrnić et al. 2001).

Although hydrometeor classification algorithms are robust, some limitations to purely polarimetric-based identification techniques have been recently identified, particularly during winter precipitation. Numerical weather prediction thermodynamic data and surface temperature reports may be used to partially mitigate these limitations.

The National Severe Storms Laboratory's (NSSL) Warning Decision Support System – Integrated Information (WDSS-II) can easily incorporate data from multiple sources (Lakshmanan 2002), and was used to develop and test these new classification procedures. Data from the prototype polarimetric WSR-88D at the NSSL (KOUN), Rapid Update Cycle model output, and Oklahoma Mesonet surface data collected during a significant winter storm on 3-4 December 2002 were used for testing and evaluation.

The 3-4 December winter storm produced a wide variety of precipitation types. A band of significant freezing rain was observed from west central to north central Oklahoma, just northwest of KOUN. Farther northwest, snow was the primary observed precipitation type. Over the southeast quadrant of the KOUN observation area, mostly rain was observed. This variety of precipitation types at close range to the radar provided an excellent test case.

3. USE OF NWP DATA FOR HYDROMETEOR CLASSIFICATION ON RADAR PPI SCANS

Conventional radar reflectivity at horizontal polarization does not provide enough information for meaningful hydrometeor classification. Polarimetric radar variables such as differential reflectivity and co-polar correlation coefficient, however, can be used to provide a bulk hydrometeor classification in a radar sample volume(Straka et al. 2000). Polarimetric radar data have been particularly useful in the discrimination between meteorological and nonmeteorological scatterers.

Light rain and light snow have been found to partially overlap in polarimetric radar characteristics (e.g., Fig. 1). To discriminate between these two precipitation types, a bright-band detection procedure has been developed and tested (Giangrande and Ryzhkov 2004). The “bright-band” is a region of radar echo marking wet snow aggregates in the melting layer of falling precipitation. This melting layer has well-defined polarimetric signatures (Zrnić et al. 1993). After detecting the altitude of the bright-band, hydrometeor classification techniques can be adjusted to only allow snow above the altiude of the bright-band signature, and only allow rain below it.

The bright-band identification procedure, however, may be limited in several cases. Very light precipitation, consisting of small, dry snow crystals or drizzle drops, may not be associated with a significant bright-band signature. Further, neither “warm-growth” rain events nor snow falling through completely sub-freezing temperature profiles would have a bright-band. Finally, due to increasing altitude of the radar beam with distance from the radar, the bright-band may be below the lowest available elevation for precipitation events at long range from the radar.

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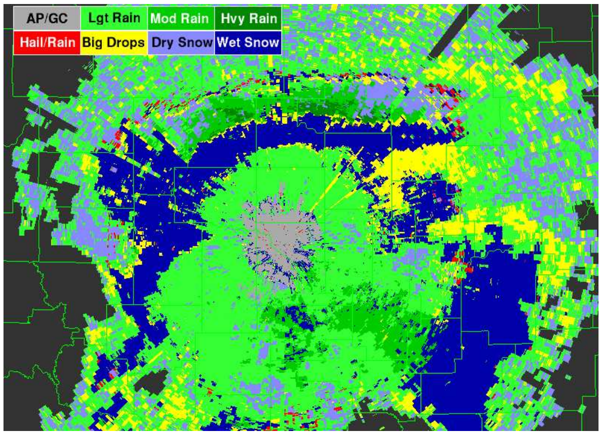

Figure 1. Example of polarimetric hydrometeor classification output, using no model thermodynamic data, at 0.5 degree elevation angle, 4 December 2002 at 0226 UTC.

To enhance hydrometeor classification in these situations, numerical model output may be used. Due to its hourly update interval, the Rapid Update Cycle (RUC) model was used for testing on the 3-4 December 2002 case. Using WDSS-II, the altitudes of the 0°C and 4°C wet bulb temperature in the RUC data were determined. These temperatures have been found to correspond well with the top and bottom of the melting layer, respectively, during this event (Giangrande and Ryzhkov 2004).

As in the bright-band detection procedures, rain was not allowed above the bright-band altitude, and snow was not allowed below it in the RUC technique. An example of the output on a 0.5 degree PPI elevation scan is shown in Fig. 2.

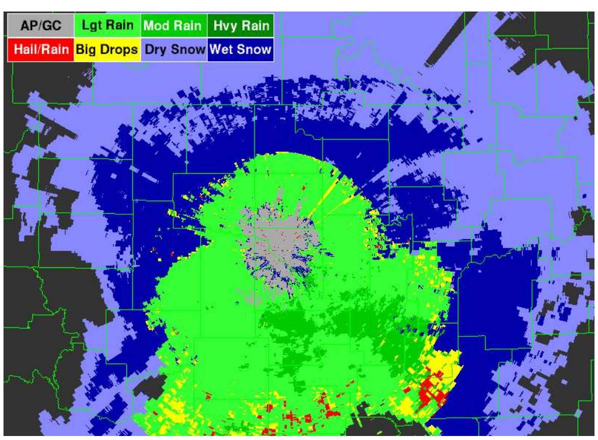

Figure 2. Example of polarimetric hydrometeor classification output, using polarimetric radar data and Rapid Update Cycle model thermodynamic data, at 0.5 degree elevation angle, 4 December 2002 at 0226 UTC.

Due to the significant slope of the melting layer (downward traveling from south to north through the radar site), rain appears at much higher altitudes to the south and southeast of the radar. This observation is reasonable given the regional soundings, which showed much higher 0°C levels to the south.

The RUC model procedure was also tested alongside the bright-band procedure for a summer case exhibiting a well-defined bright-band signature. The procedures yielded very similar hydrometeor classification output, suggesting the RUC method may be a useful substitute when the bright-band technique is not available, such as in our test case.

4. CREATION OF SURFACE PRECIPITATION TYPE PRODUCT

Polarimetric hydrometeor classification algorithms are intended to depict scatterer types on the plane of the observed data. In the case of the WSR-88D, the algorithm output is on a series of conical surfaces (corresponding to radar PPI elevation scans). However, many users are interested in fields of surface precipitation type. In many cases, the surface precipitation type can be extrapolated from the type observed on the lowest radar elevation angle. However, regions of freezing rain at the surface cannot be explicitly determined without incorporating thermodynamic data from other sources.

The RUC model thermodynamic data were used along with KOUN data to provide a smooth field of estimated surface precipitation type (an example is shown in Fig. 3). Polarimetric data at the lowest elevation (0.5 degrees) were used to first discriminate between precipitation and non-precipitation regions. Where precipitation was detected at the lowest tilt, a precipitation category was assigned at the surface, based on a simple technique using data from the RUC model.

In regions where no temperatures above freezing were observed in the temperature profile, snow was depicted as the surface precipitation type. Elsewhere, rain was the first guess of surface precipitation type, no matter what type of hydrometeor was detected at the lowest radar tilt. In regions where rain was the first guess, the RUC data were further interrogated for surface wet bulb temperature. In areas where rain was falling with wet bulb temperatures below freezing, the rain category was changed to freezing rain.

During the 3-4 December 2002 case, this technique generally worked quite well, when compared qualitatively to observed surface precipitation type reports. The model's surface wet bulb temperatures, however, were higher than the observed temperatures, leading to a depiction of freezing rain over a smaller area than was observed.

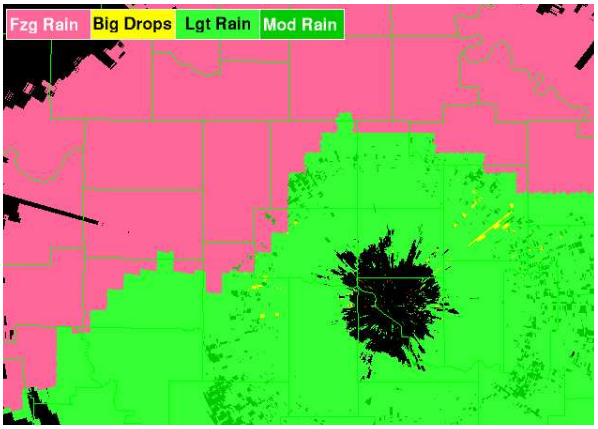

Figure 3. Example of surface precipitation type output using polarimetric radar data and Rapid Update Cycle model thermodynamic data, 3 December 2002 at 1900 UTC.

5. USE OF OKLAHOMA MESONET TEMPERATURE DATA TO ENHANCE SURFACE PRECIPITATION TYPE PRODUCT

In order to improve the deliniation in the surface precipitation field between rain and freezing rain, the RUC data aloft were combined with surface temperatures observed by the Oklahoma Mesonet, a dense network of automated real-time surface observation stations. An example of this output is provided in Fig. 4. As expected, the rain-freezing rain line was much more accurately represented.

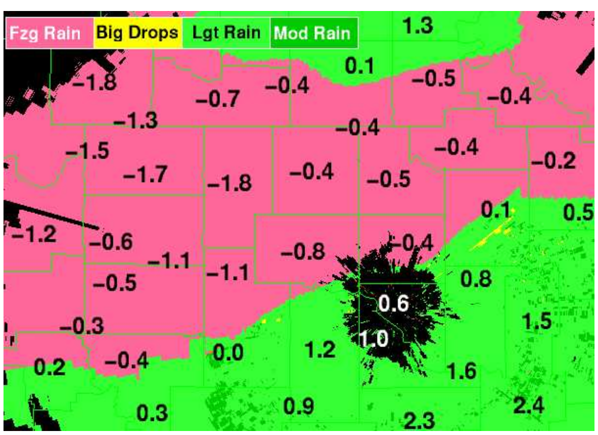

Figure 4. Example of surface precipitation type output using polarimetric radar data and Oklahoma mesonet surface temperature data (degrees Celsius), 3 December 2002 at 1900 UTC.

6. DISCUSSION AND CONCLUSIONS

Polarimetric radar data allow a much more accurate depiction of hydrometeor types than ever before possible. Polarimetric classification techniques work quite well without assistance in most circumstances. Discrimination between light rain and light snow, however, can be challenging when no well-defined bright-band signature is present. Additionally, freezing rain at the surface cannot be explicitly observed by radar.

In the case of the 3-4 December 2002 winter storm, a variety of precipitation types were observed by KOUN polarimetric WSR-88D and surface stations. Rapid Update Cycle model thermodynamic data refined the polarimetric hydrometeor classification on PPI scans, particularly where light precipitation dominated. A simple technique to map a smooth field of surface precipitation type using RUC thermodynamic data was successful. The identification of freezing rain areas was also aided by ingesting surface temperature data from the Oklahoma Mesonet.

Results from this case suggest a successful technique to determine surface precipitation type could involve the use of polarimetric data to discriminate meteorological from nonmeteorological scatterers, temperature profiles from numerical model thermodynamic data to deliniate regions of liquid versus frozen precipitation, and surface temperature observations to identify regions of freezing rain. The use of numerical model output on the PPI scans themselves would be more limited to an enhancement of the existing polarimetric techniques, particularly in regions of very light precipitation and echoes at long ranges from the radar.

More data sets need to be collected and examined to identify strengths and weaknesses of these procedures. Qualitative studies such as this will need to be followed up with quantitative studies when more data become available. Further testing is expected using existing and future winter storm events observed by the prototype polarimetric WSR-88D.

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