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**RESEARCH PROJECT TITLE**
The Pavement Precipitation Accumulation Estimation System—Further Development – Aurora Project 2009-05

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Aurora is an international partnership of public agencies performing joint research, evaluation, and deployment initiatives related to road weather information systems (RWIS).



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# The Pavement Precipitation Accumulation Estimation System—Further Development

project summary

## Background

Wintertime precipitation has profound impacts on surface transportation. The ramifications include decreased public safety, compromised traveler mobility, diminished productivity of roadway users, and adverse environmental effects due to the need to chemically treat icy roads.

## Problem Statement

Individual sources of information regarding wintertime precipitation suffer from significant limitations. With radar, specifically the National Weather Service WSR-88D Doppler Radar network, the primary issues are overshooting and inherent uncertainties in estimated precipitation rate values.

Overshooting arises because, under typical propagation conditions, radar beams rise to increasing altitudes with increasing range. This results in radar being unable to sense precipitation beyond a certain range. When this is coupled with the fact that wintertime precipitation systems tend to be shallower than summertime systems and with the spacing of radar within the US (which was based partially upon the depths of summertime systems), the result is wintertime systems not being detected with the existing radar network over large areas of the US.

The second principal limitation of radar data is inherent uncertainties in precipitation rates. These can arise, in extreme cases, from virga, in which precipitation is believed to be occurring based on radar data but is not reaching the ground. The limitation also arises due to inherent uncertainties in the relation between what is measured with radar, radar reflectivity factors, and the desired quantity, liquid-water-equivalent precipitation rate.

Surface data also suffer from significant limitations when estimating precipitation rates. These limitations include poor spatial resolution of the precipitation field, which can be an exceptionally severe problem in regions where surface observation station density is low. The limitations also include inherent uncertainty in liquid-water-equivalent precipitation rates, which again result from uncertainties in the relation between these rates and what is used to estimate them (visibility).

Although they utilize sophisticated data assimilation methods, model precipitation fields are known to suffer from both phase (location) and amplitude (intensity) errors. These errors arise both from inadequacies in observed fields and from weaknesses inherent with the modeling systems.

Consequently, use of one source of information regarding wintertime precipitation will result in significant inaccuracies. The combination, or fusion, of information from multiple sources, however, may enable enhanced analysis performance. The Pavement Precipitation Accumulation Estimation System (PPAES) was designed such that precipitation field analyses could be produced using individual sources of information and multiple sources of information. When multiple sources are utilized, PPAES algorithms are designed to take advantage of data strengths and mitigate data weaknesses to maximize analysis quality.

## Research Objective

The purpose of this project was to extend previous PPAES development to explore: 1) the fusion of radar and surface analyses—including the use of both Automated Surface Observing System/Automated Weather Observing System (ASOS/AWOS) data and Clarus data, 2) the fusion of radar and model data, and 3) the performance of an enhanced radar algorithm and a radar+model blending algorithm in complex terrain.

## Methodology

To quantify algorithm performance, data are verified using ASOS/AWOS data. While these data have limitations, some of which are highlighted in this study, they do provide the best readily-available verification data for this study. Verification for analyses that include the use of ASOS/AWOS data was accomplished through employment of a data denial scheme. In addition to performance metrics including probability of detection (POD), equitable threat score (ETS), and root mean square error (RMSE) for surface analyses, the statistical significance of performance differences were also analyzed.

The radar+surface blending algorithm was based upon the premise that radar would generally provide relatively accurate depictions of precipitation fields at locations that are near them; whereas, surface data would be needed at distant ranges. Based on this, algorithms for identifying the effective range of the radar were developed, depending on which radar data are used as the primary information source.

These algorithms initially produce effective ranges that are based on radar data alone. These effective ranges are then updated using surface observations. Once this process is complete, precipitation fields based on radar data and surface data are blended together to remove aesthetically-displeasing jumps in the analysis field. It is noted that in the surface analysis algorithm, less smoothing is used in areas where surface observation station density is high, so that finer-scale information regarding the precipitation field in those areas is retained.

The purpose of the radar+model blending algorithm is to enhance analysis performance in complex terrain, where radar beam blockage and low surface observation station density can present significant challenges. The first generation algorithm developed utilizes a relatively simple approach in which radar-estimated precipitation fields are replaced with model-estimated precipitation fields if the altitude of the data upon which the model-precipitation estimates are based are significantly below (user controlled) the altitudes of the radar data.

In addition to the development of blending algorithms, the PPAES radar algorithm was updated such that the user can request terrain clearance. When requested, any radar data that are within a user-requested altitude of the ground are not used in the analyses.

## Conclusions

The PPAES radar+surface blending module provided an improved probability of detection compared to the other analyses and this difference in performance is statistically significant at the 5 percent level. However, other measures of accuracy, including False Alarm Ratio (FAR) and ETS indicated that surface analyses alone performed better than radar and radar+surface analyses. Despite this, the radar+surface analyses do seem to provide a more coherent picture of precipitation fields given they provide fine-scale information near radar and precipitation filling from surface data at locations where radar overshooting is a significant problem.

Inclusion of Clarus data degraded analysis quality. While the exact cause of this is not known, possible reasons include different performance characteristics relative to ASOS/AWOS precipitation sensors and equipment maintenance practices and standards. This is an issue that requires further examination.

With the radar+model blending approach and the limited number of test cases used for this project, the addition of model data resulted in degradation of performance from the standpoint of the metrics used. However, the use of model data does have the advantage of presenting a more continuous and spatially-coherent representation of the precipitation field to the user.

The primary issue with the approach used for this research is that radar spacing is large enough in the Utah domain such that the model field is utilized over a significant portion of that domain. This results in overfilling. A useful approach in the future may be restriction of use of model data to areas that are poorly covered by both radar and surface data.

Because 1) WSR-88D radar was situated such that radar beam blockage at the lowest elevation is relatively minor, resulting in relatively small differences between radar-based analyses produced with and without terrain clearance, and 2) the surface observation network available for verification is relatively sparse, no significant enhancement in performance was observed when terrain clearance was used. However, this capability could significantly enhance analyses in non-standard radar ray propagation conditions.

## Implementation Benefits and Readiness

The winter road maintenance community can benefit from having more information about wintertime precipitation, including where precipitation is occurring and precipitation rate, leading to improvements of safety and greater cost effectiveness.

Determining wintertime precipitation occurrence and intensity is challenging. This study, in addition to providing new techniques for fusing information from multiple sources to produce enhanced wintertime precipitation analyses, identifies future research areas that may lead to even more advanced techniques that will serve the road weather community.