Evaluation of Precipitation Type from Observational Datasets to Improve Monitoring of Hazardous Winter Weather at the Storm Prediction Center

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1 Introduction and Motivation

The Storm Prediction Center (SPC) issues mesoscale discussions (MD) focusing on hazardous winter weather conditions expected in the continental United States during the six hours following MD issuance. Since precipitation type and intensity can vary significantly across a small area, a diverse set of resources such as model guidance, radar, satellite, and observations is required to provide guidance in the decision making process. As a result, tools and products that summarize information from these resources are an effective asset to SPC forecasters in creating winter weather MDs. To accomplish this, the SPC has recently taken some initial steps in the development of a gridded system to identify dominant precipitation type characteristics with the intent of incorporating multiple observational datasets.

Historically, standard surface observations in METAR format provided from ASOS/AWOS surface stations have been the only source of data at SPC for evaluating precipitation type during winter weather events. In work examining the performance of the hydrometeor classification algorithm (HCA) from polarimetric radars, Elmore (2011) has advocated that the evaluation of multiple data sources over just relying on one provides more information and better diagnosis of winter surface precipitation type. In order to address this, SPC has been decoding winter weather related local storm reports (LSR; NOAA 2016) for a few years, the characteristics of which have been discussed in Sullivan et al. (2014), and has also acquired data recently from the crowd-sourcing report type called Meteorological Phenomena Identification Near the Ground (mPING; Elmore et al. 2014).

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The primary purpose of this analysis was to compare the precipitation type reported in the three-year period of 2013-2015 from LSRs and mPING reports against those identified in the METAR observations from the surface stations. For an effective comparison between the datasets, the original categories were collapsed down to four primary ones: rain, snow, freezing rain, and ice pellets/sleet. As a result, observation matching in the current study was pursued to determine the continuity and consistency of the data on pre-determined spatial and temporal scales. Building off of similar verification work conducted by Elmore et al. (2014), the validation here should identify potential biases and overall accuracy. Ultimately, the results will hopefully guide future refinement and improvement of an observationally based, gridded precipitation-type system.

2. Data and Methodology

2.1. Data

The data for this analysis focused on weather class descriptions for every day in a 3-year period (2013-15) provided by winter-related LSRs, surface observations in METAR format, and a collection of mPING reports made available based on a partnership between the National Severe Storms Laboratory, the University of Oklahoma and the Cooperative Institute for Mesoscale Meteorological Studies. Each dataset had a different structure to delineate different attributes of the observations, which included variables such as the location expressed in latitude and longitude, date and time (expressed in UTC) of occurrence, and of course the inherently unique precipitation types. Furthermore, METAR reports also included the temperature and dewpoint at the time of the observation, which was used here for quality control. Beyond that, any other piece of information available was neglected for the purposes of this study. Finally, a gap in the mPING reports from October 2, 2013 to October 16, 2013 was noted by the authors. Thus, proper adjustments were made to remove the same time period from the LSRs and METAR observations when performing comparisons between the datasets to ensure an accurate and fair evaluation.

2.2. Methodology

First, each observation record was classified into four, broad precipitation categories based on one of often several precipitation types contained within the datasets. Grouping of the data into rain, snow, sleet, and freezing rain categories was required to conduct comparisons since some classifications were either exclusive (e.g., Blizzard in LSRs) or involved mixed precipitation. The broad classification scheme of winter precipitation used for the LSR and mPING reports is shown in **Table 1** and **Table 2,** respectively. For the conventional, surface METAR observations (**Table 3**), there were a variety of different descriptors that are assigned to the present weather group (e.g., such as '+' for heavy, '-' for light, 'TS' for thunderstorm, 'SH' for shower and 'VC' for vicinity) but no distinction is made here in documenting these variations within the four precipitation classes. Additionally, in mixed precipitation cases for the METARs, there was no specification of what precipitation type was most dominant. Therefore, for the purposes of this study, this assumption was made for the first precipitation type listed in the record and was what was selected for further evaluation.

An additional step taken in the classification process was a quality control check of the METAR observations based on temperature to make sure the precipitation type reported was appropriate. Specifically, if the recorded temperature of a freezing precipitation type was greater than 5°C, then the report was not included in the analysis. On the other hand, if the temperature of a rain METAR was less than 0°C, then it was also not included. After this quality control check was completed, a count of all remaining METAR observations was produced, which is shown in **Table 3**.

LSR Type	LSR Type Report Count	Broad Precipitation Category	Total for Category
Snow	155,730	Snow	177,911
Heavy Snow	21,432		
Blizzard	758		
Freezing Rain	7,163	Freezing Rain	8,107
Ice Storm	944		
Sleet	3,183	Sleet	3,183

Table 1: Count of each winter-related LSR type for a 3-year period spanning 2013-15 (second to left column) as well as the corresponding total for each broad precipitation category (right column). The width of the rows in the right two columns corresponds with the specific LSR types that are included in the broad precipitation category.

mPING Precipitation Type	mPING Type Report Count	Broad Precipitation Category	Total for Category
Rain	285,511	Rain	399,127
Drizzle	81,347		
Mixed Rain and Ice Pellets	14,085		
Mixed Rain and Snow	18,184		
Snow and/or Graupel	193,101	Snow	225,226
Mixed Rain and Snow	18,184		
Mixed Ice Pellets and Snow	13,941		
Freezing Rain	14,238	Freezing Rain	22,532
Freezing Drizzle	8,294		
Ice Pellets/Sleet	34,650	Sleet	62,676
Mixed Ice Pellets and Snow	13,941		
Mixed Rain and Ice Pellets	14,085		

Table 2: Same as in Table 1 except for precipitation type classes given in mPING report dataset. Any one data point identified as containing "mixed" weather elements is not mutually exclusive and will contribute to two broad precipitation categories.

Broad Precipitation Category [METAR Notations]	Total for Category
Rain [RA and DZ]	2,115,857
Snow [SN]	798,767
Freezing Rain [FZRA and FZDZ]	22,351
Sleet [PL]	1,318

Table 3: Same as in Table 1 except for the present weather group reported in the METAR surface observations. No breakdown is attempted for the broad precipitation categories but rather implicitly included various, common descriptors (e.g., such as '+' for heavy, '-' for light, 'TS' for thunderstorm, 'VC' for vicinity and 'SH' for shower, etc.) in the analysis.

Once all of the reports were organized into broad precipitation categories, the different datasets were then compared to determine if the precipitation type matched. For the current study, the results from either the LSR or mPING data were evaluated against just sleet and freezing rain METAR observations, which was used as the reference for ground truth. In particular, only LSR/mPING reports that occurred within 60 minutes and 100 kilometers of the ASOS/AWOS surface station were retained as reasonable candidates. This process resulted in three possible designations: 'MATCH' for a matched pairing, 'MISMATCH' for a mismatched pairing (e.g., freezing rain, rain, or snow occurs in close proximity to sleet), or 'NO MATCH' for when there was no LSR or mPING report identified within the spatiotemporal window. Again, any possible matches corresponding to the missing mPING data in October 2013 were removed.

To visually represent this matching system, a case study of a winter weather event is shown in **Fig. 1**. This figure displays every mPING and LSR that reported within 1 hour and 100 kilometers of a METAR at Minneapolis-St. Paul on February 10, 2013 at 1553 UTC. In this case, there were many more mPING reports than there were LSRs. Only two reports, represented by square symbols in **Fig. 1**, were found in the defined spatial and temporal window. At this time, the METAR reported sleet as the precipitation type occurring at the station. The mPINGs and LSRs in **Fig. 1** show that snow was the dominant precipitation type northwest of the METAR. Moving from northwest to southeast, precipitation type gradually shifts to sleet and freezing rain, before finally becoming mostly all rain southeast of the METAR.

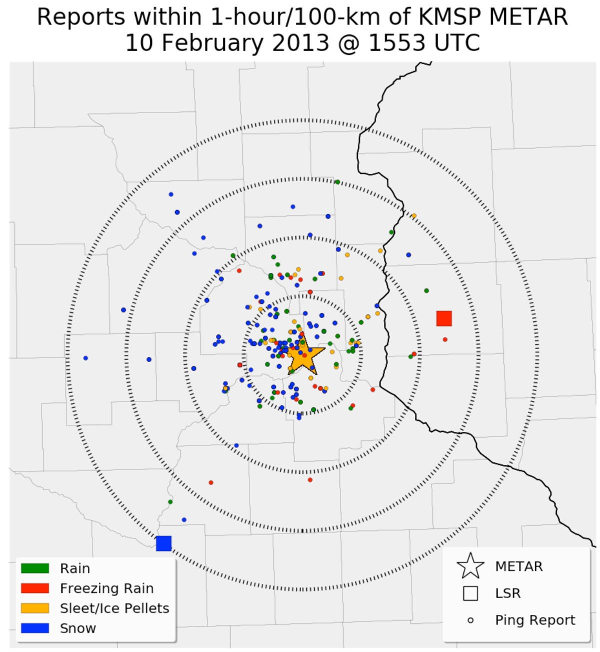

Fig. 1. Case study of all LSRs and mPINGs within 1 hour and 100 km of a METAR at KMSP. Each ring represents 25 km from the surface station. Report and precipitation type are represented by symbols and colors respectively.

3. Results

3.1. Distance Matching of Precipitation Type

Many of the results comparing accuracy in precipitation type relative to distance from the surface METAR observation show a noticeable shift. For example, the boxplot of freezing rain distance matches between the METAR and mPING reports is shown in **Fig. 2**. In this plot, the quartiles for matched pairings are shifted down to lower distance values when compared to the quartiles for mismatches. This indicates that there was more likely to be a match between the METAR and mPING report if the two occurred closer together.

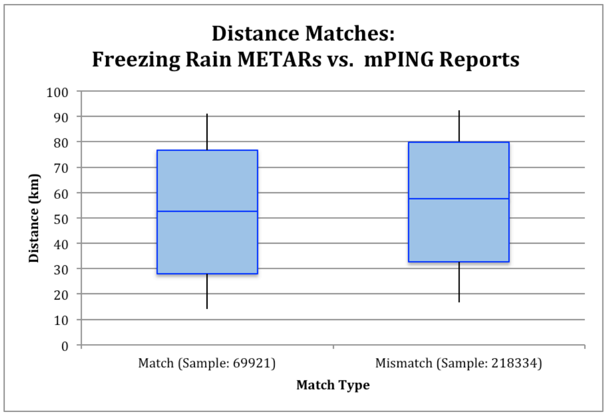

Fig. 2. Boxplot of match and mismatch distance (in km) pairings for freezing rain METARs compared with all mPING reports from 2013-2015.

A similar trend is also noted in the boxplot of freezing rain distance matches for LSRs, which is shown in **Fig. 3**. Once again, the boxplot of the mismatches is shifted up to higher distances compared to the matches. This is supported by the fact that the median distance for matches is about 60 kilometers, while the median distance for mismatches is about 67 kilometers. In spite of the similarities, though, most LSRs are usually found slightly farther away from the ASOS/AWOS surface station compared to mPING reports (compare distributions in **Fig. 2 to Fig. 3**).

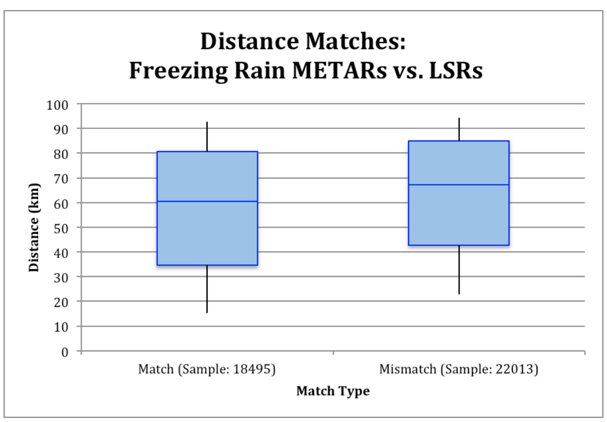

Fig. 3. Boxplot of match and mismatch distance (in km) pairings for freezing rain METARs compared with all LSRs from 2013-2015.

The pattern identified in **Figs. 2** and **3** continues for the matched sleet reports as well. **Fig. 4** shows the boxplots of the matches and mismatches between sleet METARs and mPING reports. Like the freezing rain matches, the sleet matches distribution is shifted to lower distances compared to the mismatches boxplot. An examination of **Fig. 4** reveals that the median match distance is 38 kilometers, while the median mismatch distance is 46 kilometers. Interestingly, though, the medians of the sleet distance matches for both boxplots is approximately 10 kilometers lower than those for freezing rain (compare **Fig. 2** to **Fig. 4**).

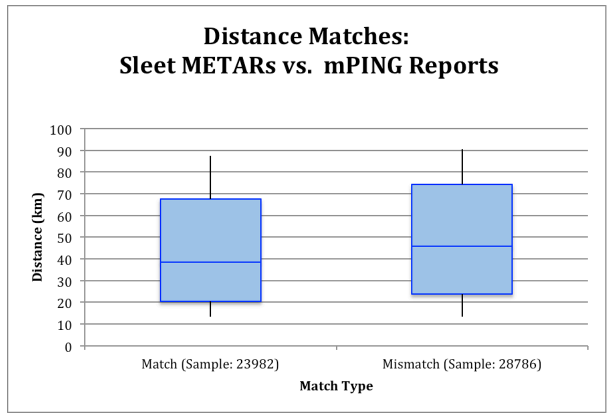

Fig. 4. Boxplot of match and mismatch distance (in km) pairings for sleet METARs compared with all mPING reports from 2013-2015.

This shifted median pattern between the matches and mismatches is even more pronounced in the boxplots of distance for sleet METARs and LSRs, which is shown in **Fig. 5**. For instance, the median of the match boxplot is about 49 kilometers, while the median of the mismatch boxplot is about 65 kilometers. Actually, the difference between these two values is much higher than any of the other analyses previously shown in **Figs. 2-4** for both LSRs and mPING reports. When evaluated against LSRs, mPING reports once again have a tendency overall to be in closer proximity to the METAR (compare **Fig. 4 to Fig. 5**).

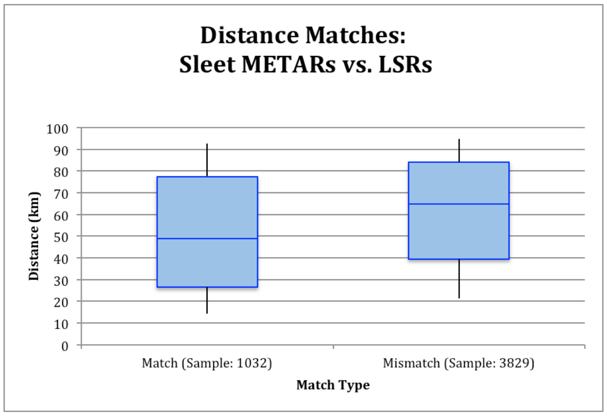

Fig. 5. Boxplot of match and mismatch distance (in km) pairings for sleet METARs compared with all LSRs from 2013-2015.

3.2. Temporal Matching of Precipitation Type

In contrast to the spatial neighborhood findings, temporal offset boxplots for sleet and freezing rain in **Figs. 6-9** do not show a shift between matches and mismatches with all medians near 30 minutes. This indicates that there is a fairly even spread in the time difference between both the METARs and LSRs and the METARs and mPING reports for both matches and mismatches. When contrasting **Figs. 6** to **7**, the inter-quartile range for matches for LSRs with freezing rain is slightly smaller than the inter-quartile range of the mismatches, unlike the similarity observed with mPING reports. This indicates that the distribution of the time difference between matched METARs and LSRs was smaller with marginally more consistent results than that of the mismatched reports.

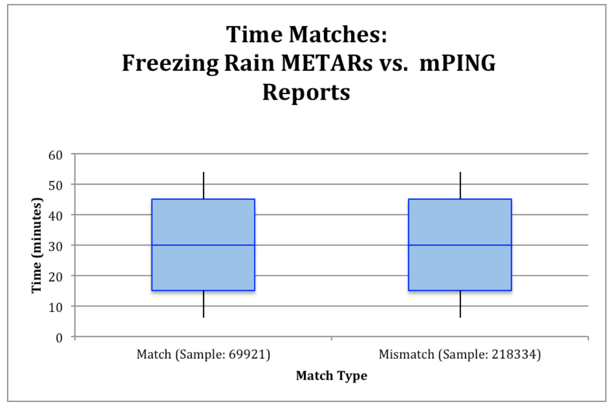

Fig. 6. Boxplot of match and mismatch time (in minutes) pairings for freezing rain METARs compared with all mPING reports from 2013-2015.

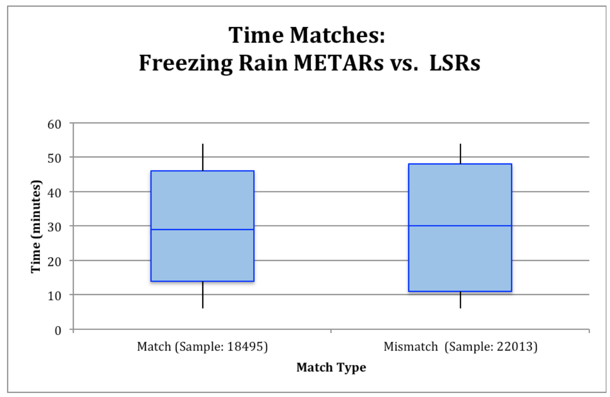

Fig. 7. Boxplot of match and mismatch time (in minutes) pairings for freezing rain METARs compared with all LSRs from 2013-2015.

The relationship between sleet observations is shown in **Figs. 8** and **9**, and the plots are similar to **Figs. 6** and **7**. Given the nearly identical features, there appears to not be a correlation between shorter time differentials and matched precipitation types. Additionally, this is further supported by equal spread between the 10th and 90th percentiles of the match and mismatch boxplots with a difference of 48 minutes.

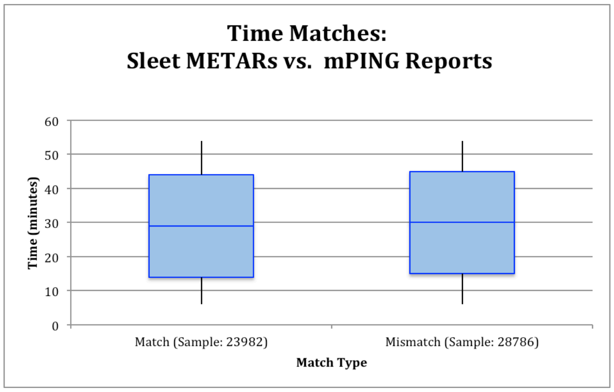

Fig. 8. Boxplot of match and mismatch time (in minutes) pairings for sleet METARs compared with all mPING reports from 2013-2015.

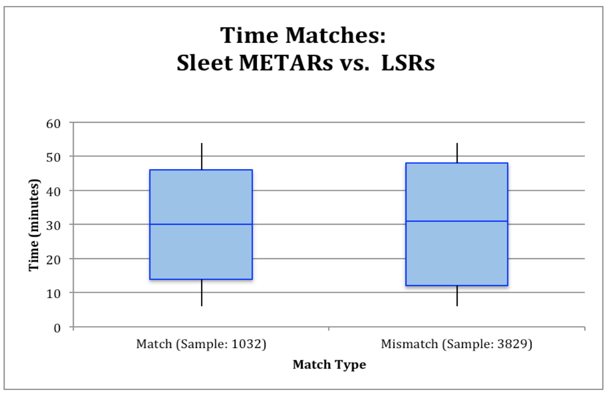

Fig. 9. Boxplot of match and mismatch time (in minutes) pairings for sleet METARs compared with all mPING reports from 2013-2015.

3.3. Aggregate Matching of Precipitation Type

The number of total matches, mismatches, and no matches for precipitation type between each report type is shown in **Table 4**. There are many more mismatches between the two report types than matches. Freezing rain and sleet have a match percentage less than 50 percent. Sleet LSRs and freezing rain mPING reports have the lowest match percentage, which was 21.2 percent and 24.2 percent, respectively. Freezing rain LSRs have the highest percentage amount of no matches, with 25.8 percent of METARs having no corresponding LSR within the spatiotemporal window of one hour and 100 kilometers. In contrast, sleet mPING reports have the lowest percentage amount of no matches, with 0.2 percent of METARs having no corresponding mPING report within the defined distance and time. Clearly, missing mPING reports were less likely to occur given the much higher sample sizes compared to LSRs (**Table 5**).

	Freezing Rain METARs		Sleet METARs	
Match Type	Matching with mPING Reports	Matching with LSRs	Matching with mPING Reports	Matching with LSRs
Match	69921	18495	23982	1032
Mismatch	218334	22013	28786	3829
No Match	6422	14114	126	688
Match Percentage	24.2	45.7	45.4	21.2
No Match Percentage	2.2	25.8	0.2	12.4

Table 4: Total number of match, mismatch, and no matches from 2013-2015 for LSR and mPING reports for sleet and freezing rain precipitation types from the surface METAR observations. The match and no match percentages are also included in the table. Matches are valid within a 100 kilometer radius and 60 minutes of a surface METAR observation.

The distribution of precipitation type counts for LSRs and mPING reports are shown in **Table 5**, which helps to identify the exact breakdown of both matches and mismatches given in **Table 4**. To be clear, a mismatch means that the METAR precipitation type is not the same as the precipitation type of the LSR or mPING report, with two (three) possible categories for the LSR (mPING report). For example, if the sleet METAR had no match, then a corresponding LSR would have to be either freezing rain or snow since rain was not part of the classification process for this dataset.

Table 5 reveals greater consistency overall in freezing rain identification compared to sleet, presumably related to the greater occurrence of the former. On the other hand, the most common mismatch for freezing rain METARs and mPING reports is sleet. This conclusion makes some sense because normally the occurrence of sleet and freezing rain are spatially close to one another. However, the most common mismatch for freezing rain METARs and LSRs is snow, with sleet totals being well below those identified as snow. Finally, the most common mismatch for sleet METARs is snow for both LSRs and mPING reports (**Table 5**).

	Freezing Rain METARs		Sleet METARs	
LSRs or mPING Precip. Type	Matching with mPING Reports	Matching with LSRs	Matching with mPING Reports	Matching with LSRs
Rain	69595	0	9402	0
Snow	51420	17599	15471	3092
Sleet	97319	4414	23982	1032
Freezing Rain	69921	18495	3913	737

Table 5: Total count of LSRs and mPING reports from 2013-2015 within a 100 kilometer radius and 60 minutes of a freezing rain or sleet surface METAR observation and its associated precipitation type.

4. Summary and Conclusions

4.1. Summary

The SPC has developed an initial prototype for a gridded system to determine dominant precipitation type characteristics but the current work investigates means on how to better merge and utilize multiple observational datasets. In this study, classifications of precipitation from two unconventional report data types were obtained to identify biases based on their spatial and temporal proximity when matched to standard surface observations across the contiguous United States. First, the precipitation types available in the LSR and mPING report datasets over the course of a three-year period (2013-2015) were grouped into four broad precipitation categories. Then, these grouping were compared against freezing rain and sleet identified from the present weather group in METARs issued at ASOS/AWOS surface stations. More specifically, a broad spatiotemporal neighborhood was applied to consider all reports within 60 minutes and 100 kilometers of the location of the ASOS/AWOS. From this diagnosis, identical or different precipitation types when compared with the nearby METARs were either given the 'MATCH' or 'MISMATCH' match designation, respectively. Alternatively, a 'NO MATCH' description was assigned to a particular METAR observation without any LSRs or mPING reports in the vicinity of the surface station.

4.2. Conclusions

The results here suggested that the distance between different report types has a much more significant impact on the similarity of precipitation type compared to surface METAR observations than the time between reports. The median distance for ''MATCH' pairings for each comparison is always less for LSRs and mPING reports than the median distance for 'MISMATCH' pairings. In contrast, the median time of both 'MATCH' and 'MISMATCH' pairings is approximately 30 minutes for each comparison against the METARs. This implies that the time difference between reports did not have a significant impact, since this is also the median on the 60-minute timeframe chosen for this study.

Implementation of these results into the gridded precipitation system at SPC would require assigning more weight to the distance between reports rather than the time separation between them. Again, this is supported based on the analysis using the spatial and temporal constraints used in this study, where distance has a much more significant effect than time based on the likelihood of a 'MATCH' pairing between data types. Additionally, smaller distances between sleet reports should be given more weight than freezing rain reports. The median distance was below 50 kilometers for 'MATCH' pairings for sleet reports, while the median distance was over 50 kilometers for 'MATCH' pairings for freezing rain reports.

Additionally, there are a greater number of mPING reports closer to the ASOS/AWOS stations than LSRs. This is consistent with the distributions of the distance between the METAR and the other data types that show that there is a greater likelihood to have an mPING report near an ASOS/AWOS station than an LSR. Therefore, the SPC should weigh mPINGs to a greater extent because there are a higher number of reports in this data type than LSRs. Since the data resolution is better and consistent with the surface METAR observations, the reports from this experimental dataset will give a better idea of what kind of winter weather is occurring in a given area.

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References

Elmore, K.L., 2011: The NSSL hydrometeor classification algorithm in winter surface precipitation: Evaluation and future development. Wea. Forecasting, 26, 756–765, doi: 10.1175/WAF-D-10-05011.1.

__________, Z.L. Flemig, V. Lakshmanann, B.T. Kaney, V. Farmer, H.D. Reeves, and L.P. Rothfusz, 2014: mPING: Crowd-sourcing weather reports for research. Bull. Amer. Meteor. Soc., 95, 1335–1342, doi:10.1175/BAMS-D-13-00014.1.

NOAA, cited 2016: Multi-Purpose Weather Products Specification, National Weather Service Directive 10-517 [Available online at http://www.nws.noaa.gov/directives/sym/pd01005017curr.pdf].

Sullivan, B.T., C.J. Melick, R.M. Mosier, I.L. Jirak, and C.D. McCray, 2014: The Usefulness of Winter Weather Local Storm Reports at the Storm Prediction Center. Preprints, 39th Natl. Wea. Assoc. Annual Meeting, Salt Lake City, UT, Natl. Wea. Assoc., P1.9.