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The Utility of a High Resolution Volunteer Snow Observer Network

by

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1. Introduction

The evaluation of a winter storm event is often done using observations of total snowfall and liquid equivalent. Ironically, during winter field programs, the dataset necessary to compile just such information is often quite sparse, both spatially and temporally. Standard surface measurements of snowfall and liquid equivalent from first order National Weather Service SAO sites are only taken every three hours, and these sites are typically separated by ~ 100 km. To further enhance the number and temporal resolution of snowfall measurements, automated snowgauges have been made available as an option on the National Center for Atmospheric Research (NCAR) Portable Automated Mesonet (PAM) stations. However, these snowguages can be inaccurate, especially in situations where significant winds and/or snow with low liquid content occur.

During the winters of 1990 and 1991, the Winter Icing and Storms Program (WISP) was conducted in northeastern Colorado. This extensive field program was designed to study the structure and evolution of winter storms, with emphasis placed on improving the understanding of the processes which lead to the production and depletion of supercooled liquid water in clouds (which can be a significant hazard to aircraft). As part of this program, a network of approximately 100 volunteer snow observers was implemented. This paper will describe the snow observer network, give some examples of the usefulness of this dataset for both snowfall and icing events which occured during WISP operations, and suggest further uses of such datasets for future winter field programs.

2. The WISP Volunteer Snow Observer Network

The WISP field program employed a dense array of instrumentation in northeastern Colorado for the winters of 1990 and 1991 (see Figure 1). A detailed description of the WISP90-91 field networks is available in Rasmussen et. al. (1992). To augment the data available from such standard instruments as surface mesonet stations, soundings, radars, aircraft and satellites, a network of approximately 100 volunteer snow observers was developed. The observers, who ranged from meteorologists at NCAR and Colorado State University to high school students from the Colorado eastern plains, recorded values of snow accumulation, snowfall rate, liquid equivalent, crystal habit, degree of riming, and aggregate occurrence and size on simple checklist type forms. The time resolution of the data varied from 30 min to 6 hr. Overall storm data were also recorded, including snowfall period, total accumulations of snow and liquid equivalent, as well as additional information about rainfall, lightning, drifting and general comments about the character of the precipitation event. This information is critical to the evaluation of each WISP event, for without it only a handful of National Weather Service first order stations (which report snowfall and liquid equivalent) and six NCAR Portable Automated Mesonet (PAM) stations equipped with R.M.

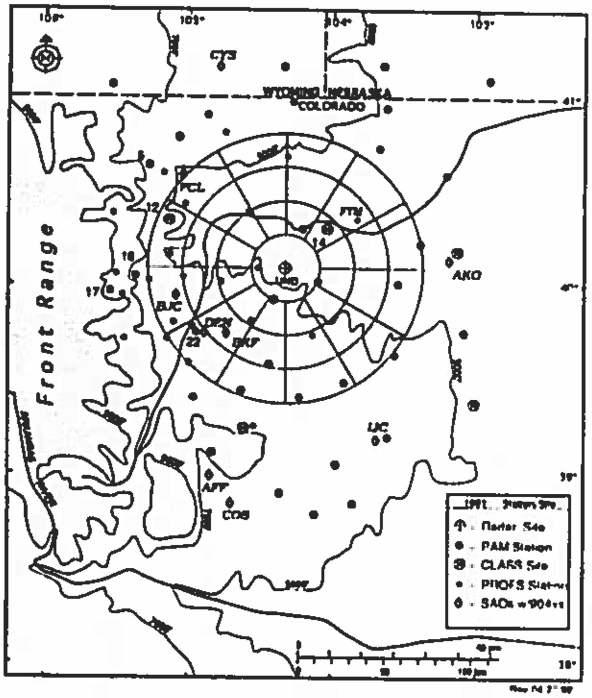

Fig. 1 *The WISP91 Mesonetwork – UND azimuth and range rings and locations of Fort Morgan (FTM), Akron (AKO), Limon (LIC) and PAM 14 (14) R.M. Young snowgauge (numbered PAM sites have snow gauges).*

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Young snowguages would be available for such tasks (see Figure 1).

3. Example cases

3.1 – A Narrow, Intense Snowband

On March 16-17, 1991 a surface low pressure system tracked across the southern extent of the WISP domain. The low moved from southwest to northeast in conjunction with a closed circulation at both 700 and 500 mb, as seen in sounding and wind profiler data (not shown). This system produced widespread snowfall and some freezing rain across the eastern portion of the WISP mesonet, including 3 inches at LIC (Limon, CO) and 2 inches at AKO (Akron, CO) (see Figure 1 for locations). All snowfall measurements in the document are reported in inches to preserve the accuracy of the original measurements.

The main precipitation feature noted in this case was a 80-100 km wide snowband. This band entered the southeastern corner of the network and moved toward the northwest at approximately 17 km/hr (band motions are according to observations by Univ. of North Dakota (UND) radar personnel). A weak extension of this band affected AKO between 1621 and 1815 (all times UTC), during which a volunteer observer reported 0.4 inches of snow. After a 95 minute period of no snowfall, the northern extent of the main snowband swept across AKO between 1950 and 2210. AKO reported heavy snow with 2 inches of accumulation as the band passed (see Table 1). UND radar plots (Figures 2a,b,c) indicate that the band moved to the west of AKO and stalled by 0000 on the 17th, with the band centered near Fort Morgan (FTM on Figure 1). It was near this time that the 700 mb low center passed to the south of FTM. As the low continued to move toward the east, the attendant band weakened and moved eastward at 11 km/hr. The weakened band again passed over AKO between 0540 and 0813, dropping only light snow and little additional accumulation.

Table 1 *Akron, CO National Weather Service (NWS) SAO's for March 16-17, 1991.*

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AKO SA 1150 W8 X 2F 129/29/26/1611/984/707 26
AKO SA 1247 W5 X 1 1/2F 132/27/26/1312/984
AKO SP 1324 W3 X 1F 1411/984
AKO SA 1349 W3 X 1F 129/29/27/1513/983
AKO SP 1427 E5 OVC 2F 1611/984
AKO SA 1448 E5 OVC 2F 128/29/27/1611/983/203
AKO SP 1520 W2 X 1/2F 1512/9985
AKO SA 1551 W1 X 1/4F 132/29/28/1416/984
AKO SA 1648 W3 X 1/2SF 130/31/30/1416/984/SB21
AKO SA 1845 E10 OVC 6F 32/M/0000/983
AKO SA 1953 W2 X 1/2SF 121/31/29/1306/981
AKO SA 2052 W2 X 1/4S+F 115/31/30/1407/980/808 90401
AKO SA 2147 W2 X 1/4S+F 115/31/29/1109/980
AKO SP 2223 E7 OVC 3S- 1211/979
AKO SA 2248 E9 OVC 7 117/30/29/1209/979/SE42
AKO SA 2350 E9 OVC 10 123/29/27/1108/981/30316 31 90402
AKO SA 0049 E9 OVC 15 132/28/27/1209/983
AKO SA 0150 E5 OVC 15 138/28/26/1108/985
AKO SA 0251 E5 OVC 10 146/28/25/1106/988/220 90402
AKO SA 0349 E5 OVC 10 151/28/26/0000/989
AKO SP 0424 E5 OVC 2 1/2F 1004/991
AKO SA 0448 E5 OVC 2 1/2F 155/28/27/0000/991
AKO SA 0551 E5 OVC 2 1/2S-F 157/29/26/0000/992/SB40/21202 31 90402
AKO SA 0649 E5 OVC 2 1/2S-F 160/27/26/2906/992
AKO SA 0750 E5 OVC 2 1/2S-F 160/27/26/0000/992
AKO SA 0849 E5 OVC 2 1/2F 163/28/25/0000/993/SE13 303
AKO SP 0914 W2 X 1/2F 2909/991
AKO SA [illegible] W2 X 1/2F 166/26/25/2808/993
AKO SA 1013 W2 X 1/2F 166/27/26/2708/993
AKO SA 1116 E10 OVC 3F 2810/993
AKO SA 1150 E10 OVC 3F 171/28/28/2909/995/30700 24 20018
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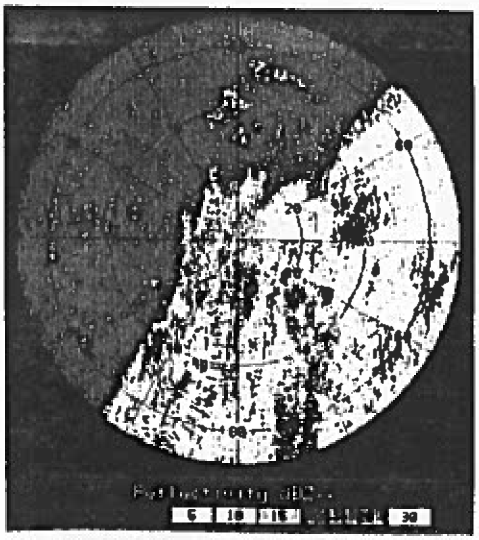

Fig. 2a *University of North Dakota 0.2° elevation reflectivity plots for 2006 UTC, 16 March 1991. Range rings are every 20 km. For locations of FTM, AKO and PAM 14, compare with Fig. 1.*

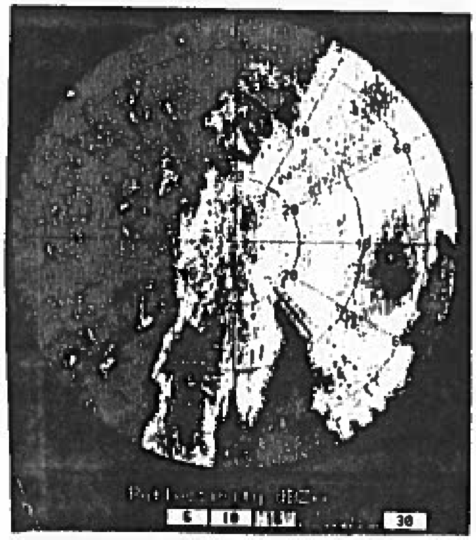

Fig. 2b *Same as Fig. 2a, 2202 UTC, 16 March 1991.*

3.1.1 - Mapping the Snowfall

Of the eight NWS stations within the network which report snowfall (904xx groups) and liquid equivalent, only four received any snowfall, and only AKO and LIC reported accumulations. Among the six PAM snowguages in place, only one (PAM 14) received snowfall (2 mm total, excluded from this analysis due to probable innaccuracy of the measurement). Satellite images taken 2 days after the event (not shown) suggest that heavier amounts of snow fell just to the west and southwest of AKO. It is clear from the radar and satellite data that the NWS data does not accurately depict the snowfall which occurred on March 16-17. By adding the volunteer snow observer network data available for this case to the NWS data, the

Fig. 2c *Same as Fig. 2a, 0005 UTC, 17 March 1991.*

resolution of the snowfall data increases markedly, and allows for a more accurate mapping of the snowfall (see Figure 3). This analysis is now in much better aggreement with the radar and satellite data. Without the snow observer network, the mesoscale snowfall distribution of this band could not have been resolved.

3.1.2 - Time-series of the Snowband

While spatial resolution of snowfall is important to the evaluation of this event, temporal resolution is equally important. Figure 4 is a time-series plot from an exceptional observer located 3 km west of Fort Morgan. The plot indicates accumulated snowfall, precipitation type and intensity, crystal habit and degree of riming. Between 1820 and 2330 the western half of the snowband passed over this site as its motion stalled. The heaviest snowfall was occurring at and just to the east of Fort Morgan at 2330, as determined by low level UND radar reflectivity plots (Figure 2). Moderate to heavy snow fell for approximately 70 minutes, resulting in one inch of accumulation during the period. This one inch per hour snowfall rate adds credence to the six inch snowfall reports just east of Fort Morgan, where the band persisted for up to six hours.

The time-series of crystal habit and amount of riming, when linked with radar, sounding and aircraft data (WISP conducted many flights along and across snowbands and other features) can give critical "ground truth" data. This information can be used to infer crystal formation zones and temperatures, amount of supercooled liquid water in the cloud, depth of the cloud and particle fall speeds. In the March 16-17, 1991 case, the observation of lightly and heavily rimed crystals during passage of the snowband correlates well with the observation of supercooled liquid water droplets within the band by University of Wyoming aircraft. For the March 6-8, 1990 blizzard, observations of graupel by volunteers were critical in the proper determination of particle fallspeeds for dual Doppler analysis (G. Stossmeister, personal communication).

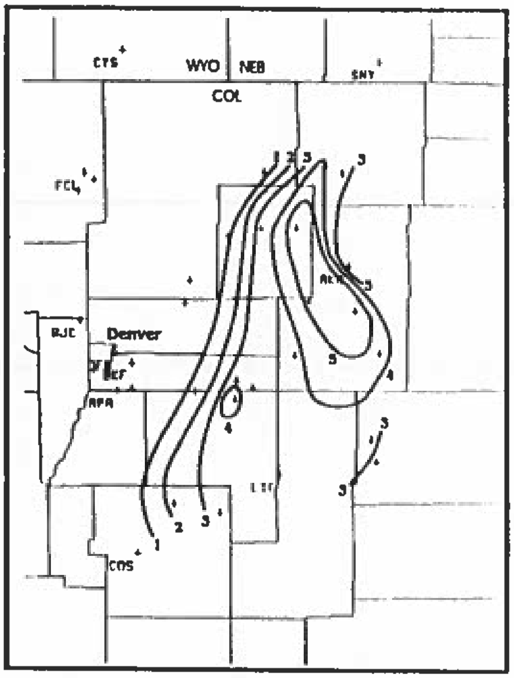

Fig. 3 *Contour map of snowfall (inches) using NWS SAO's and volunteer snow observer network data.*

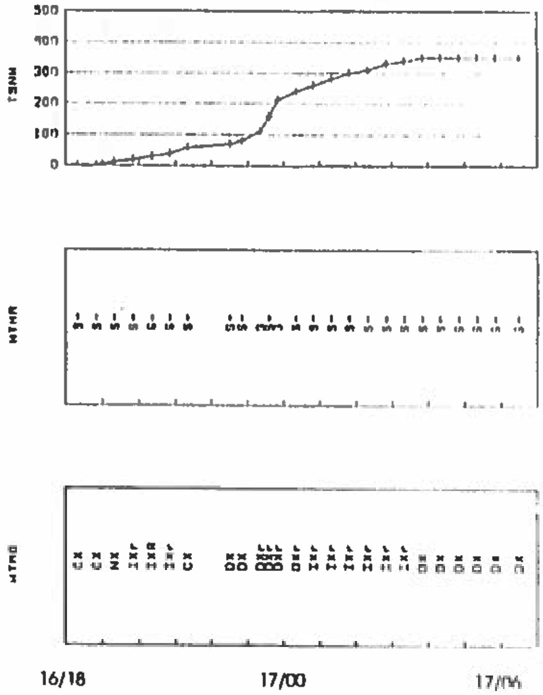

Fig. 4 *Time-series of volunteer snow observer data from 3 km west of Fort Morgan, CO. TOP — total snowfall in $\frac{1}{100}$ inches. CENTER — precipitation type and intensity (sideways). BOTTOM — crystal habit (C-columns, N-needles, I-irregulars, D-dendrites) and degree of riming (R-heavily rimed, r-lightly rimed, no letter-no rime). Plot is from 16 March 1991, 1800 UTC to 17 March 1991, 0700 UTC.*

3.2 Observer network data for other storms

Similar snowfall analyses to those presented in Section 3.1 have been performed for other case studies. Discussion of snowfall mechanisms for these storms is not included here. One example is the 30-31 March 1988 storm, which exhibited a strong east-west gradient of snowfall over the foothills and adjacent plains (Wesley and Pielke, 1990). Fig. 5 presents the snowfall distribution for this storm, based primarily on snow observer reports. The tabulation of dominant crystal habit information is shown in Table 2. The habit and riming information was used (along with other data) for specification of likely snow-producing cloud layers in this storm.

Another storm which involved lighter snowfall was the 15-16 January 1991 WISP event, in which the north-south gradient in snowfall was significant. The observer-derived distribution is shown in Fig. 6. In this case, convergence in anticyclonic flow on the south side of the Cheyenne Ridge was responsible for higher accumulation in the western portions of the WISP domain.

4. Conclusions

It is clear that the WISP volunteer snow observer network is a valuable part of the overall WISP mesonetwork. It furthers the insight we gain from remote and in situ instruments by adding "ground truth" observations of the crystals, liquid water and snowfall we could only otherwise infer through the use of radars, aircraft, soundings and satellite datasets. As with any other dataset, volunteer snow networks have their problems. Nightime cases and windy cases often produce fewer quality observations, and thus less desirable results than those presented here. However, with a dense enough network, and a great deal of patience, quality analysis can be done using this and similar datasets from other projects.

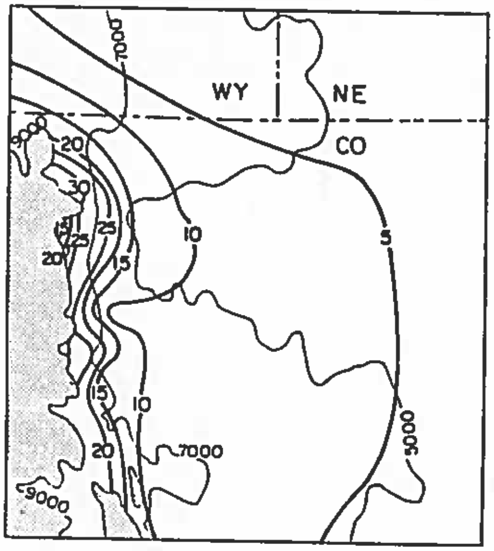

Fig. 5 *Snowfall (inches) distribution for 30-31 March 1988 cold air damming event.*

Table 2 *Snow crystal observations for the spotter network shown in Fig. 5.*

Crystal Type	Total No. Occurrences
heavily-rimed, aggregated spatial dendrites	41
heavily-rimed irregulars	29
graupel	18
rimed, aggregated plates	11
rimed sector plates	9
heavily-rimed stellars	7
unrimed stellars	4
lightly-rimed dendrites	4
unrimed plates	3

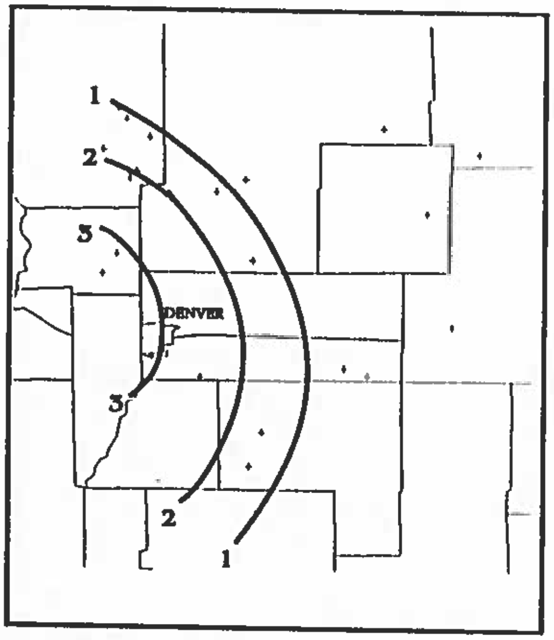

Fig. 6 *Snowfall (inches) distribution for 15-16 January 1991 case.*

Acknowledgments

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