1.2 Severe downburst winds in the Phoenix metropolitan area observed during the 2008 PUFFS field experiment

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1. INTRODUCTION

Damaging downburst winds from thunderstorms in the Phoenix, Arizona metropolitan area (PHX) are a challenging phenomenon from a forecast and warning perspective. These events also impact aviation and power distribution. However, the climatology and knowledge of the detailed structure and evolution of downbursts in the area are lacking. Vasiloff and Howard (2008) described a severe downburst event near PHX using data collected by the Shared Mobile Atmospheric Research and Teaching Radar (SMART-R) and the KIWA WSR-88D in 2004. A follow-on field project, the Phoenix Urban Flash Flood Study (PUFFS) was conducted during the 2008 monsoon season with the goal of documenting severe and flood producing thunderstorms. In addition to the KIWA and SMART-R, data were collected with the Phoenix Terminal Doppler Weather Radar (TDWR), west of Sky Harbor International airport.

Figure 1 shows the study area with locations of the three Doppler radars. The SMART-R was located at the northeast of the Metro area at a Salt River Project power generating station. The relative positions of the radars provide an opportunity for dual- and triple-Doppler airflow analyses. Note the higher terrain surrounding PHX, which is often responsible for convection initiation.

This paper provides a brief radar overview of the severe wind events that occurred on 21 July, 25 and 28 August, and 10 September 2008 (table 1). Especially of note is the 28 August outbreak that affected a large area with waves of organized line segments, two of which evolved into bow echoes. Additional mesoscale storm environment analysis of these events is underway. Web sites mentioned below provide additional information for 25 and 28 August.

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Table 1. Overview of wind event days and storm reports during PUFFS. Reports are from the NOAA Storm Prediction Center. Dates are local times. * indicates additional report search is underway.

Date	Type	Winds	Hail	Flash floods
7/21	Isolated mbs	60 mph		yes
8/25	Widespread mbs	67 mph		yes
8/28	Bow echoes	85 mph	1”	yes
9/10	Widespread mbs	60 mph	.75”	*

Figure 1. Google satellite image of PUFFS radar locations. Numbers indicate SPC wind reports for days 1, 2 and 4. Dashed line is area of most intense damage on day 3.

2. 21 JULY 2008

Activity on this day was limited to a few cells in the east valley near the SMART-R and KIWA radars. The first cell developed 6 km south of KIWA and produced a very brief microburst. The outflow/gust front from this cell resulted in a stronger microburst north of KIWA (Fig. 2). The green/red velocity couplet (Fig.

2b) is the classic pattern of diverging Doppler velocities in a microburst. The peak radial velocity was 25 ms^{-1} and coincided with a 60 mph report found in the preliminary storm reports from the Storm Prediction Center. The development and evolution of these storms are in a prime dual-Doppler analysis area. The development of successive storms along an outflow boundary is a recurring theme on all four case days.

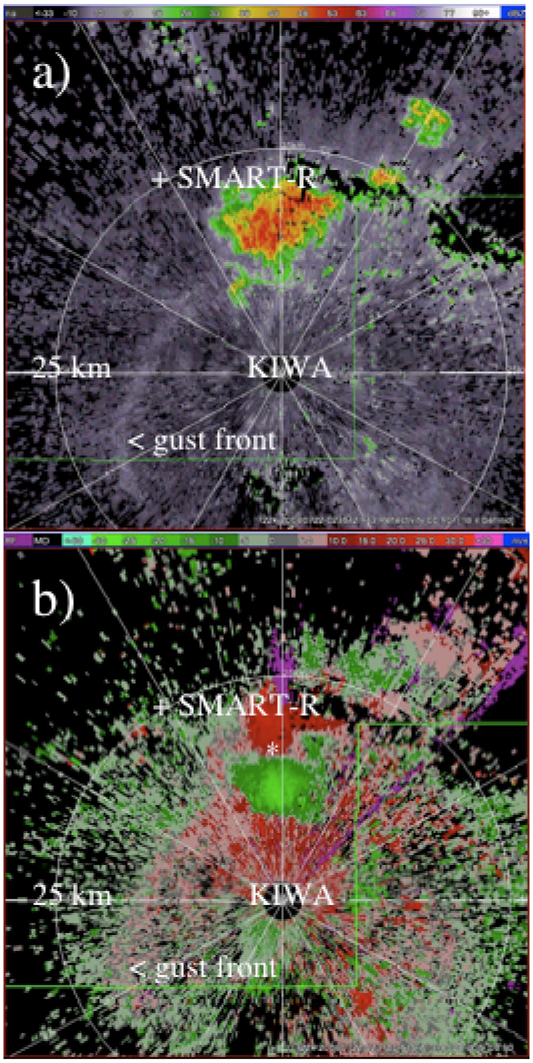

Figure 2. Images from the KIWA radar at 0237 UTC on 22 July from the 0.9 deg elevation angle of: a) reflectivity and b) radial velocity with green indicating airflow toward the radar and red away. * marks a microburst.

3. 25 AUGUST 2008

Moisture from tropical storm Julio had moved into the area (http://www.wrh.noaa.gov/psr/pns/2008/August/25thStorms.php). Downburst activity was widespread mainly in the eastern half of the area. Storms began over higher terrain and spread outflow into the valley (Fig. 3). By 2154 UTC, cells had developed almost directly over the KIWA radar. Note the multiple microburst signatures, some as small as 2 km across. Subsequent storms and outflows triggered additional storms with a concluding multiple-pulse cell complex near the airport. A second period of heavy rain and widespread flooding occurred in the early morning.

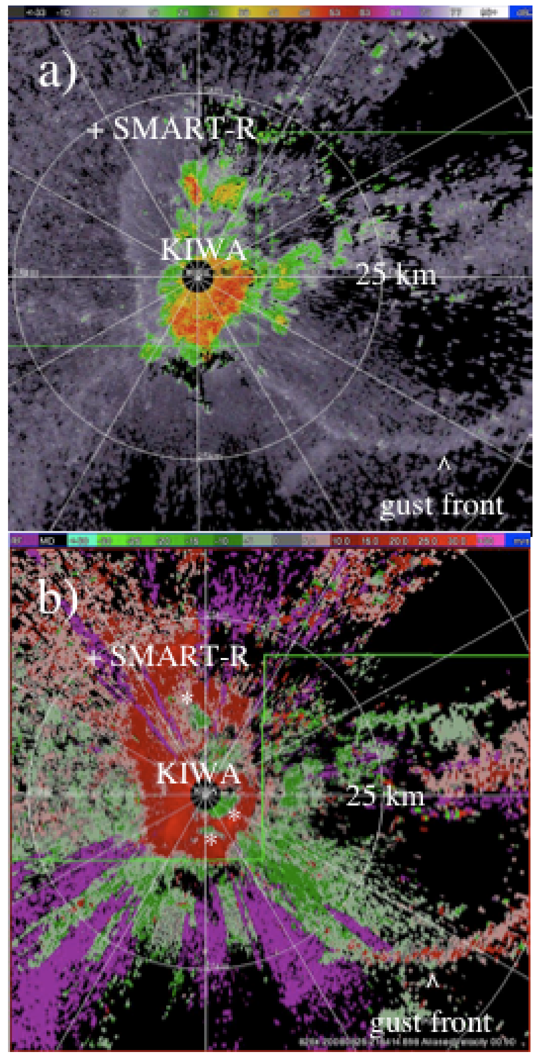

Figure 3. As in Fig. 2 except for 2154 UTC on 25 August.

4. 28 AUGUST 2008

The atmosphere was very unstable with an unusual deep layer of strong NE winds aloft, which apparently favored line segment formation and downward vertical momentum transfer

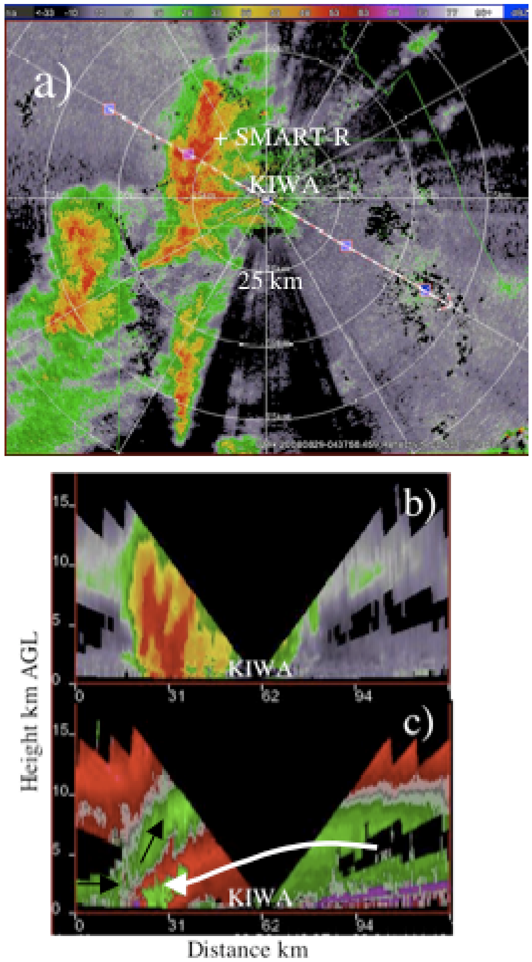

Figure 4. a) As in Fig. 2a except for 0.5 deg elevation at 0438 UTC on 29 August, b) vertical cross section of reflectivity along the dashed arrow in a), c) vertical cross section of radial velocity. Arrows indicate directions of airflow. Folded positive velocities can be seen at the tip of the white arrow.

(http://www.wrh.noaa.gov/psr/pns/2008/August/28thStorms.php). Several bow echoes (e.g., Lee et al. 1998) produced heavy rain and widespread damage. Images taken of the last of the bow echoes is shown in figures 4 and 5, just west of the SMART-R and KIWA radars. Note the severe blockage south of KIWA at the 0.5 deg elevation angle; not as pronounced at 0.9 deg (see Figs. 2 and 3). The previous bow echo is 50 – 75 km southwest KIWA. The three main lines of storms formed along the higher terrain to the east and moved westward.

Vertical cross sections shown in Figs. 4b and c show deep vertical convection along the leading edge of deep rear-to-front flow. This is similar to the descending rear inflow that forces many Midwest squall lines and bow echoes.

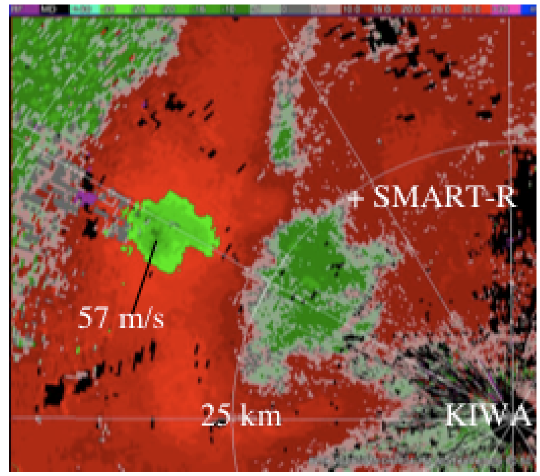

Figure 5. As in Fig. 4a except for radial velocity. The 57 ms^{-1} velocity is in an area of folded outbound (red) velocities.

Doppler velocities change sign or “fold” at the Nyquist interval which depends on the radar characteristics. The green inside the red areas seen in Figs. 4c and 5 indicate the peak velocities with a maximum of 57 ms^{-1} at 0438 UTC. The data are ~800 m above the surface and coincided with significant damage.

5. 10 SEPTEMBER 2008

Microbursts were also widespread on 10 September. However, there was only one report of severe winds that was associated with the Mesa cell 25 km and 290 deg from KIWA (Fig. 6). Note that there were at least five microburst signatures in various stages of development at 0313 UTC.

6. SUMMARY AND FUTURE WORK

A significant number of severe wind events were observed on four days during the 2008 PUFFS experiment near Phoenix, AZ. Most of the events were traditional downburst/microbursts except for the bow echoes on 28 August. The most significant wind damage occurred on 28 August with bow echoes, widespread wind damage, large hail and heavy rain. 25 August and 10 September had widespread microburst storms compared to just a few on 21 July. Multi-cellular storm structure was preferred for the isolated events. In addition, storms typically formed on higher terrain to the east of PHX and propagated to the west along outflows.

Additional work is underway to document the storm environments and peak winds and their relationship to reported damage, including downed power lines. There exists a significant opportunity to uniquely perform multiple-Doppler analyses using the SMART-R, KIWA, and TDWR radars. These data will also add to the climatology of PHX area downbursts.

Note: This paper, including additional high-resolution images, will be made available at http://www.nssl.noaa.gov/projects/nmq-ql/.

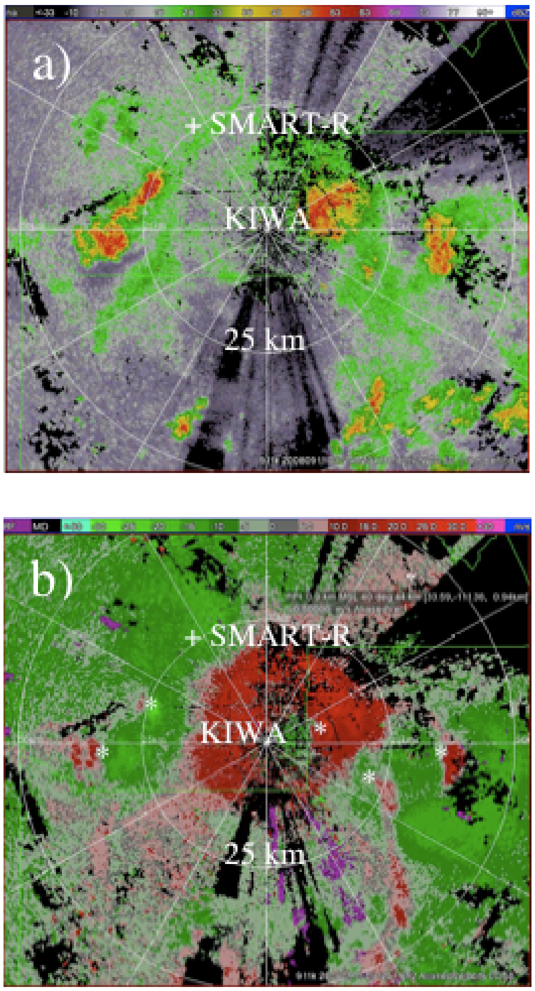

Figure 6. As in Fig. 2 except for 0313 UTC on 11 September.

ACKNOWLEDGEMENTS

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Lee, W.C., R.M. Wakimoto, and R.E. Carbone, 1992: The Evolution and Structure of a “Bow–Echo-Microburst” Event. Part II: The Bow Echo. *Mon. Wea. Rev.*, **120**, 2211–2225.

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