CoCoRaHS Hail Reports Support the Analysis of Weather Radar Data Collected during a Significant Hailstorm.

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Introduction:

The data provided by CoCoRaHS observers is often critical in identifying the local variations of thunderstorm precipitation. Hail production is generally confined to the more intense portions of a thunderstorm's overall life cycle, so hail areas are often smaller features within the storm's precipitation swath. This makes CoCoRaHS observations especially useful in mapping hail regions. The existence of hail can also be inferred from weather radar data. This summary provides an example of the benefits that detailed CoCoRaHS observations can add to the interpretation of radar data collected in a damaging hailstorm.

The hailstorm presented here affected much of the city of Greeley, Colorado during the early evening hours of Sunday, 29 July 2018. Hail damage was widespread; the storm was the headline story in the following day's edition of the Greeley Tribune (Fig. 1).

Greeley Tribune

MONDAY JULY 30, 2018

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GREELEY, COLORADO
$1.25 VOL. 147 NO. 271

SEVERE WEATHER

Hailstorm hammers Greeley, Evans

By Tyler Silvy
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When a severe thunderstorm dropped golf ball-sized hail on a large swath of Greeley on Sunday, two dozen people at Bittersweet Park had one place to go.

The pavilion on the west side of the park usually shelters picnic tables. On Sunday, it was a group of kids and parents taking part in a youth barbecue with Christ Community Church.

Youth Pastor Stetson Beaman said he was checking his phone regularly, and had the kids under the pavilion about 10 minutes before the massive hailstorm hit.

"It was pretty deafening underneath the metal roof," Beaman said, adding that it was probably the largest hail he had seen.

As kids chatted away and avoided hail-induced puddles, Beaman waxed nostalgic.

"It was interesting to remember what it was like to be a kid in these storms, and not be a car owner or a home owner where you're worried about your car and your roof," Beaman said. "(The kids) were like, 'This is amazing!'"

The aforementioned car owners or homeowners would probably disagree about the "amazing part," as the massive storm affected a large chunk of the city, shattering windows and battering vehicles and foliage and leading to at least one crash involving injuries.

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To check out reader-submitted photos from the storm and view a video, go to www.greeleytribune.com.
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A5: Hailstorm

TYLER SILVY/tsilvy@greeleytribune.com
CARS DRIVE THROUGH STANDING water Sunday after a massive hailstorm battered Greeley and Evans.

Figure 1: Front page coverage of the Sunday, 29 July 2018 hailstorm as presented in the next day's paper. (Reproduction provided by Tyler Silvy of the Greeley Tribune.)

CoCoRaHS hail reports:

A map presentation of the hail reports from this storm as provided by CoCoRaHS observers in the immediate Greeley area is shown in Figure 2. The numerical values are the maximum reported hailstone diameters in inches. The symbols used to mark the observation sites depict the general degree of hail damage: A plus sign indicates major structural damage (broken windows, roof damage, etc.; a square represents minor damage (torn plant leaves, etc.), and an open diamond indicating no reported damage. (Only one such report occurred near the northeast corner of the map). The CoCoRaHS hail report pattern shows that large, damaging hail occurred in a northwest – southeast oriented swath located generally over the western portion of the city of Greeley.

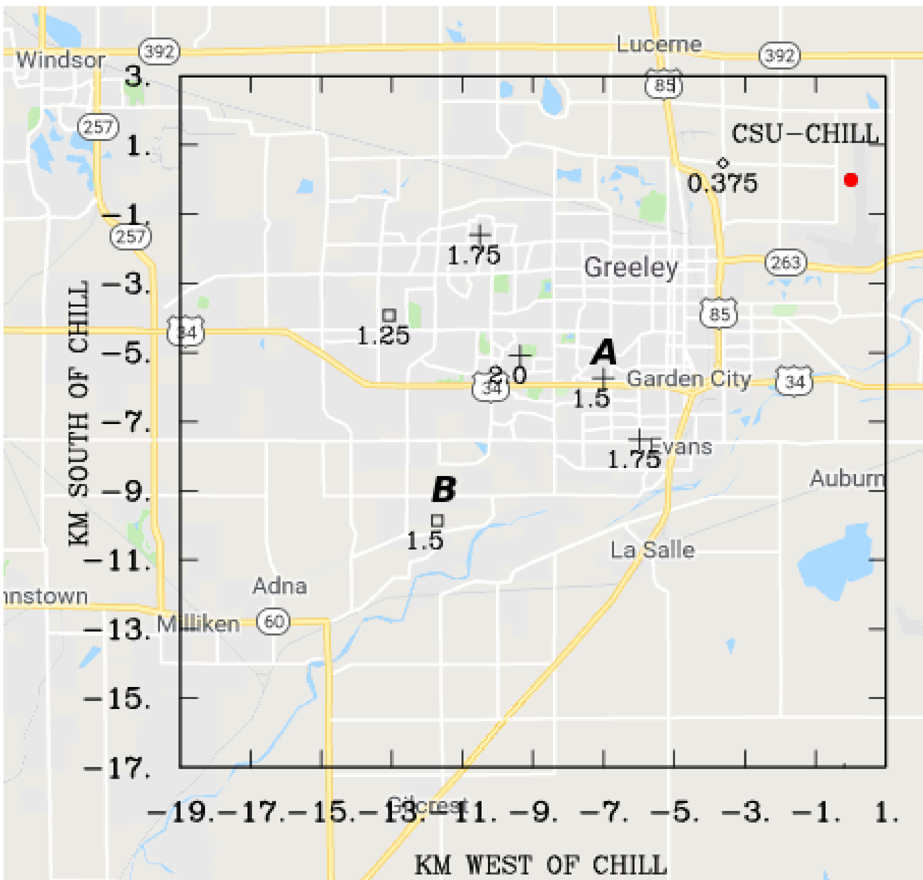

Figure 2: Map of Greeley area CoCoRaHS hail reports from the 29 July 2018 hailstorm. Numbers are maximum hail diameters in inches. Plot symbols indicate hail damage categories: plus sign = structural / automobile damage; square= minor, primarily vegetation damage; open diamond = no damage. Black perimeter box indicates distances in km from an origin at the CSU-CHILL radar (red dot in northeast corner). This same grid point box is used in the following radar data plots.

CSU-CHILL radar data:

As the storm moved across Greeley, the CSU-CHILL research weather radar located next to the Greeley – Weld County Airport (red dot in Fig. 2) was collecting data. This radar was originally developed as a joint effort of the University of CHicago and the University of ILLinois, providing the alphabetic basis for the CHILL name. (For additional information on the radar, see the chill.colostate.edu website.) As the hailstorm of 29 July 2018 moved into the Greeley area, the scanning of the CHILL antenna was adjusted to perform continuous 360 degree sweeps at an elevation angle of 2.2^{o}. This scan pattern gave observations of the near-ground storm structure at time intervals of approximately 90 seconds.

Figure 3 was constructed by recording the maximum radar reflectivity recorded at fixed set of grid points during the 7 to 7:45 PM MDT period. Reflectivity is a measurement of the strength of the returning echo signal received at the radar. It is primarily a function of the diameters and number concentrations of the precipitation particles that are illuminated by the transmitted radar pulse. The yellow swath of reflectivity values greater than 63 dBZ represents intense received signal levels. The presence of relatively large diameter hailstones generally increases the reflectivity to a level above that produced by raindrops. As depicted in Fig. 3, the maximum reflectivity swath encompassed most of the CoCoRaHS reports of damaging hail.

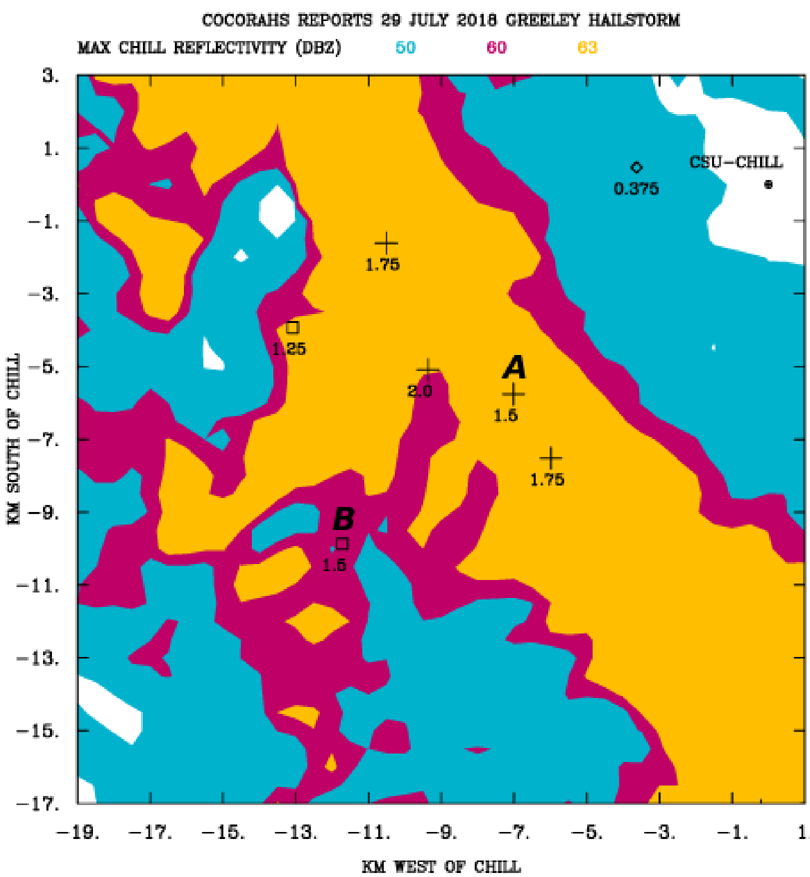

Figure 3: Color-coded plot of the highest CHILL reflectivity values recorded during the hailstorm's passage over Greeley. Contour values in dBZ: Blue=50; red=60; yellow=63. CoCoRaHS hail reports and plot domain location as in Fig. 2.

Figure 4 shows the swath of maximum Linear Depolarization Ratio (LDR) values; it was constructed from the same series of CHILL antenna sweeps that were used in Fig. 3. Unlike basic reflectivity, the measurement of LDR requires data collection using a suitably configured dual polarization radar. During this operation, the CHILL radar was transmitting pulses with a vertically-oriented electric field. The received signal was resolved into both vertically and horizontally-polarized components. The polarization state of the transmitted pulse defines the co-polar direction. At the CHILL's 11 cm wavelength, most of the signal power received from cloud drops and precipitation particles will remain in the transmitted / co-polar sense. However, the non-spherical shapes and wobbling orientations that are typical of falling hailstones cause them to shift an increased fraction of the returned signal power into the cross-polar direction relative to cross-polar return from raindrops. LDR is the ratio of the cross and co-polar signal levels (in this case, the H/V received signal powers), so areas of enhanced LDR within a thunderstorm precipitation swath should be associated with hail.

The highest LDR values displayed in figure 4 are the contained within the yellow regions where levels greater than -19 dB levels were attained. (For reference, an LDR of -20 dB indicates that the cross polar power level is .01 (one percent) of the co-polar level). The CoCoRaHS reports of structural hail damage (plus symbols) were located in or very close to regions that experienced both high reflectivities and enhanced LDR values. It should be noted that LDR is not an infallible indicator of hail damage potential. For example, the LDR from a given hailstone diameter is generally enhanced when melting produces liquid water on the outside or within the hailstone's ice structure. The plots shown here provide an example of the small scale, but important, dual polarization radar signal patterns that are typically observed in hail swaths.

Differing hail characteristics revealed by CoCoRaHS data:

The utility of the supplemental hail observations provided by CoCoRaHS observers is apparent from the information submitted by the observers located at points A and B in the preceding figures. At both locations, the maximum hail diameters were 1.5 inches. At point A, the observer remarks included hail pad destruction and automobile body denting. In contrast, at point B, the hail was reported as being mostly about .25 inches in diameter, with just a few 1.5 inch diameter stones present. Only minor leaf damage was noted at point B. It is likely that the higher concentration of larger diameter hailstones observed at point A vs. point B was responsible for the differences in the damage severity and radar signal levels observed at these two locations. The expanded information provided by CoCoRaHS observers, such as descriptions of hailstone shapes, size distributions, hardness, etc. is a significant improvement over basic reports that only include maximum hail size. The dedicated data collection efforts of CoCoRaHS observers provide valuable support to the documentation and understanding of precipitation variations on small size scales.

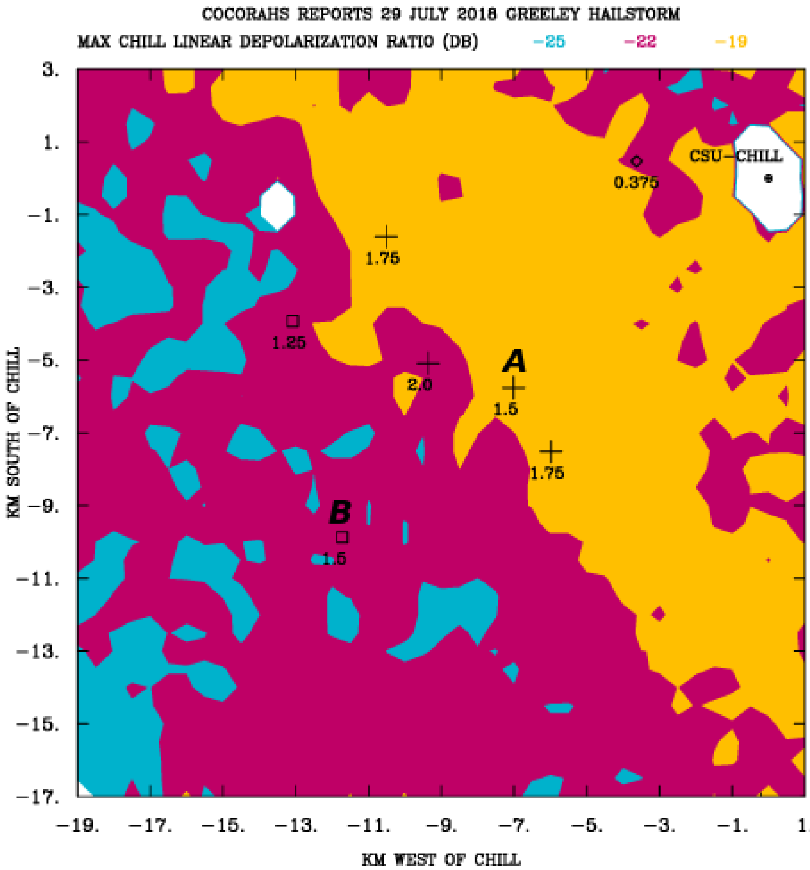

Figure 4: Swath of the maximum Linear Depolarization Ratio (LDR) values recorded at 11 cm wavelength by the CSU-CHILL radar during the 29 July 2018 Greeley hailstorm. Transmit polarization was vertical and cross-polar channel was horizontal. Contours in dB: Blue=-25; red=-22; yellow=-19.