STATE CLIMATE EXTREMES COMMITTEE MEMORANDUM

FROM: Russ Schumacher, Colorado State Climatologist, Colorado Climate Center, Dept. of Atmospheric Sciences, Colorado State University (SCEC Convener), on behalf of: State Climate Extremes Committee (Schumacher, Bonsall, Umphlett, Kearns, Arndt)
DATE: 3 October 2019
SUBJ: Colorado State Record Hailstone near Bethune

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Summary

Several supercell thunderstorms generated severe weather across much of Colorado's High Plains on 13 August 2019. One supercell, which crossed Kit Carson County during the afternoon, left very large hail near Bethune. Several stones were retrieved, the largest of which was observed, handled and measured by members of the State Climate Extremes Committee (SCEC) or partnering institutions. The following dimensions of this stone were examined by the SCEC to determine their validity and potential status of the largest such values to be directly measured of a hailstone in Colorado:

- Location: **Approx 8 mi. NNW of Bethune, Kit Carson County, Colorado**
- Date: **13 August 2019**
- Diameter: **4.83 inches**
- Weight: **8.5 oz**
- Circumference: **12.875 inches (traditional method)**
- Volume: **16.549 cubic inches**

After considering the retrieved stone and various surrounding factors, the ***SCEC determined these values to be valid, and establish the Colorado state records for these dimensions.*** The diameter value supersedes the previous unofficial, but widely held, record of 4.5 inches, observed on approximately 20 occasions since the mid 1900s. The other dimensions establish the initial official records for Colorado.

About the SCEC

This State Climate Extremes Committee (SCEC) was composed of members representing five institutions: the National Weather Service (NWS) Weather Forecast Office in Goodland, Kansas (WFO Goodland, which has warning responsibility for Kit Carson County, CO), the NWS Central Region's Cooperative Observer Program leadership, the Colorado Climate Center (CCC, the state climate office), the High Plains Regional Climate Center, and the National Centers for Environmental Information. It is convened to adjudicate potential records for validity. If validated, the observation is considered the state record for that record type. More details about the SCEC are available online at https://www.ncdc.noaa.gov/extremes/scec/details.

About the Observation

On the evening of Tuesday, 13 August 2019, the Colorado Climate Center received a report via social media of a potential record hailstone, from Brian Bledsoe, a broadcast meteorologist in Colorado Springs. This section is written from the perspective of the Colorado Climate Center and its partners.

Fig. 1: Tweet from Brian Bledsoe reporting the potential record hailstone.
https://twitter.com/BrianBledsoe/status/1161414743606743040

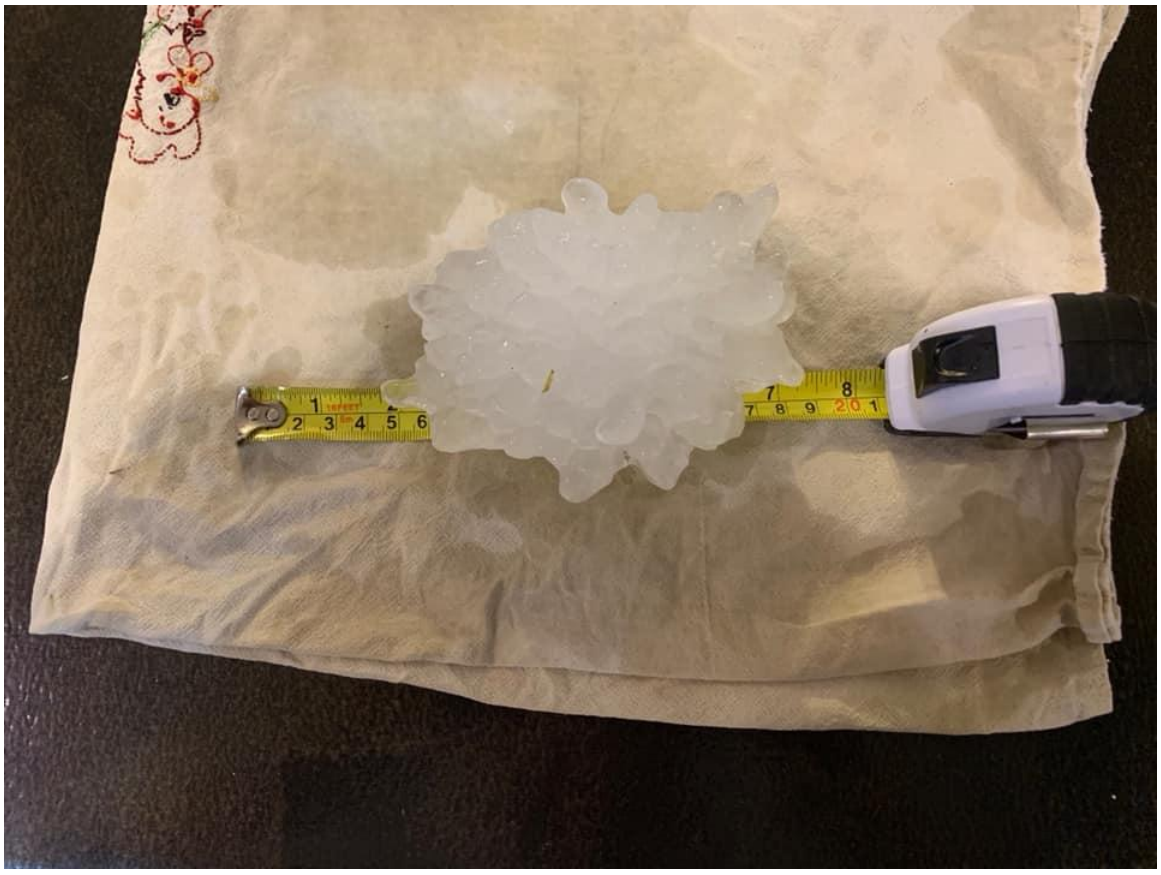


Fig. 2: Original photo of the hailstone (courtesy Kylee Miltenberger).

Colorado did not previously have an SCEC-certified hail record, but NWS severe weather records show numerous occurrences of 4.5" diameter hail, which we have long considered the state record. (See details at http://climate.colostate.edu/records.html).

Following from this report, we contacted with the National Weather Service office in Goodland, Brian Bledsoe, and the Miltenberger family (Dan and Kylee) who collected the hailstone, and made plans to visit their home northwest of Bethune, Colorado on Wednesday 14 August.

We visited their home at 1pm on 14 August 2019. Present were representatives of the CCC (Schumacher and Bolinger) and NWS Goodland (Bonsall, Thede, and Newman), as well as a reporter from KKTV in Colorado Springs. The person who collected the stone (Kylee Miltenberger) noted that it was probably 30 minutes between when the hail fell and when they placed it in a plastic bag in the freezer. The large stone was kept in the same plastic bag as two other smaller (but still big!) hailstones in the freezer. She noted that it fell at approximately 3:00pm local time.

We measured the maximum diameter with calipers and measured a maximum diameter of 4.83” from lobe to lobe. We also measured a weight of 8.5 oz, and circumference of 12.875” on the major axis and 9.375” on the minor axis.

Ms. Miltenberger also commented that the stone had lost mass and was “less spiky” when we measured compared to when it first fell.

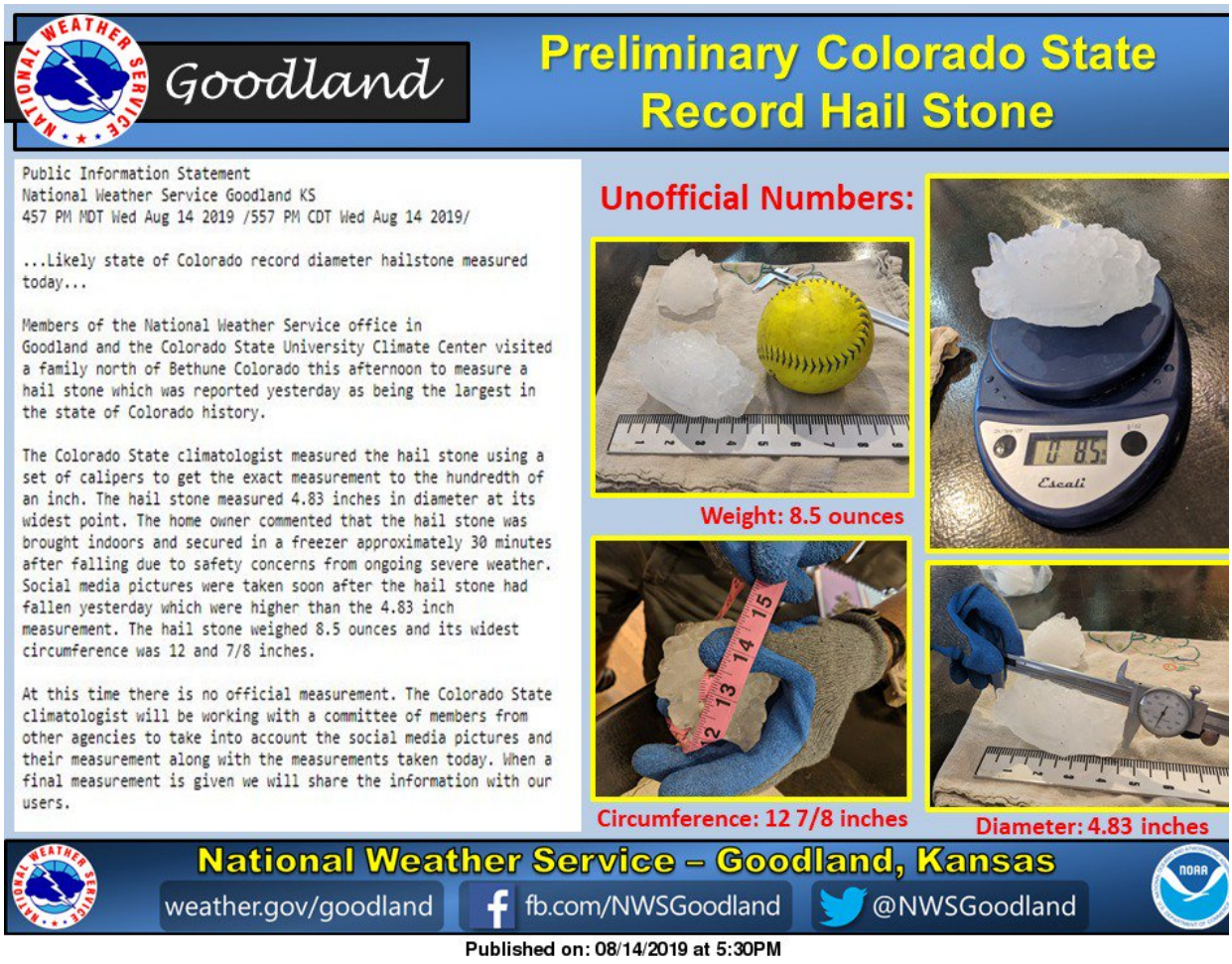


Fig. 3: Tweet from NWS Goodland with the Public Information Statement and relevant photos. *https://twitter.com/NWSGoodland/status/1161782309080772608*

3-D Scanning of the Stone

Several days later, on Sunday, 18 August 2019, representatives from the Insurance Institute for Business and Home Safety (IBHS) hail study visited the observers to do a 3D laser scan (Giammanco et al. 2017, BAMS) of the stone. They then transported the stone to the cold lab at NCAR in Boulder for preservation and further study. The IBHS team (Maiden and Giammanco) reported the results shown in Table 1.

Table 1: Results of the IBHS 3D scan of the August 2019 Bethune hailstone.

Volume	Mass	Density	Min. Diameter	Max. Diameter	Z	Surface Area
271.1895 cm^3	239 g	0.8813 g /cm^3	62.814 mm	118.618 mm	81.686 mm	271.922037 cm^2
16.549 in^3	8.43 oz		2.47 in	4.67 in	3.216 in	42.148 in^2

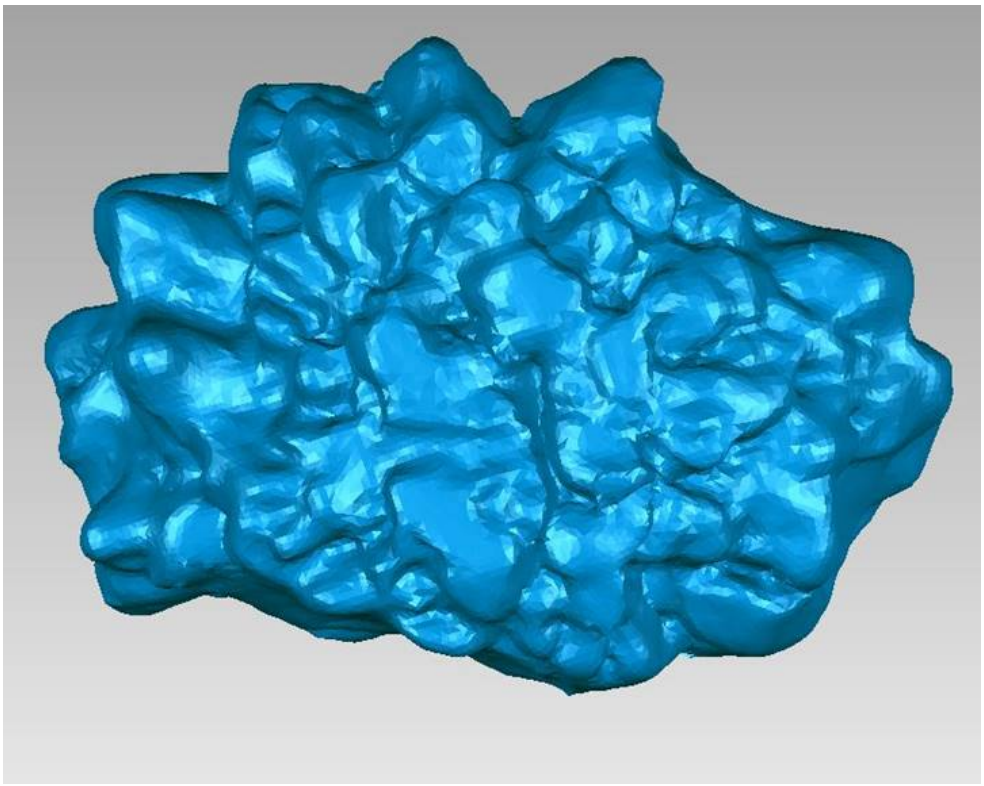


Fig. 4: Image from 3D scan of hailstone, provided by IBHS.

Some of these values are slightly lower than were measured in the field, owing to additional melting/sublimation in the time since the initial measurements. On the other hand, the 3D scan can provide additional detail that was difficult or impossible to measure in the field.

The IBHS also calculated the maximum circumference of the hailstone from the 3D scan. This uses a cross section through the stone, and measures the circumference including all lobes (Fig. 5). This yields a circumference of 14.5 inches. Such a circumference would be nearly impossible to measure with a tape measure (as the tape measure would need to be wrapped carefully between all of the lobes). Considering these factors as well as previous precedent of establishing hailstone records (e.g., the Alabama record in 2018), this method for measuring circumference will not be used in the official record, but the information is included here for completeness and to demonstrate another capability of 3D scanning technology.

Of course, considering the time between the initial hail fall and the preservation of the stone in the freezer, and in light of the photo taken shortly after its retrieval, the stone was likely greater than 5” in diameter when it fell. The original photo with the ruler suggests that the stone was likely greater than 5” in diameter when it was first measured.

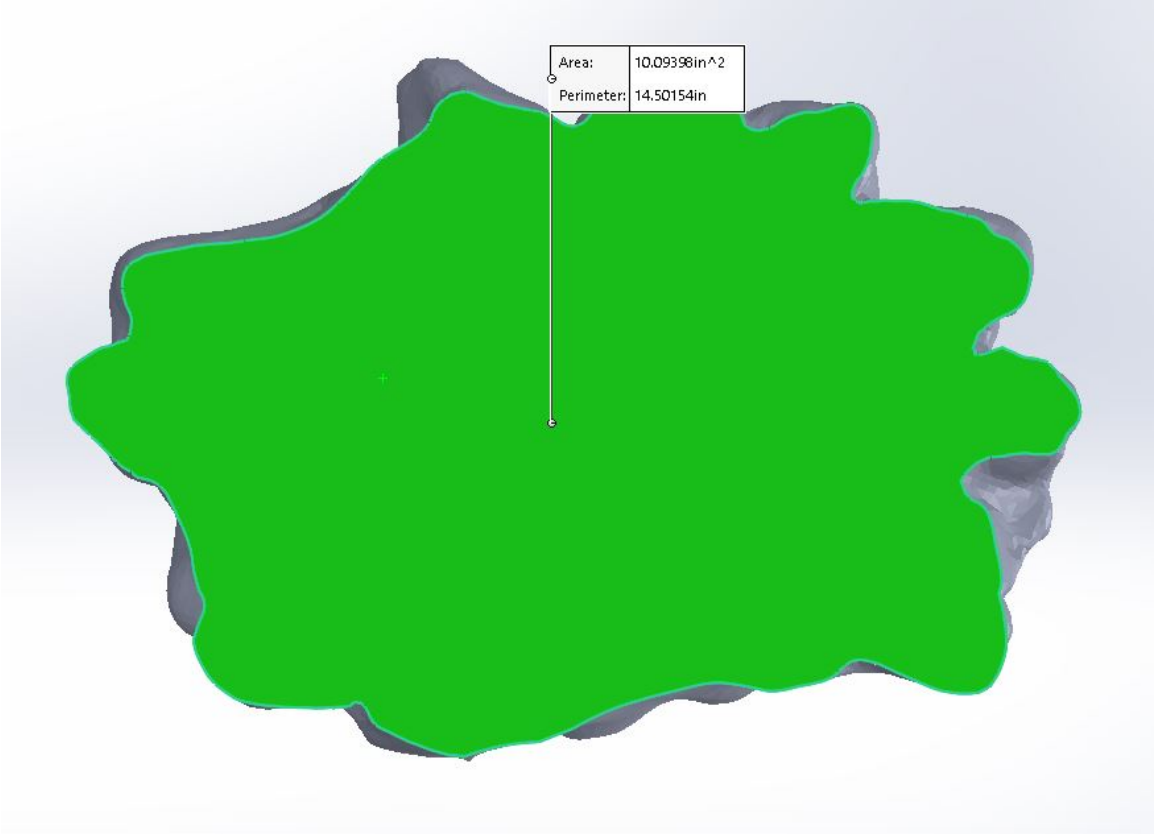


Fig. 5: Cross-section of stone from 3D scan, provided by Ross Maiden of IBHS. It reveals a circumference of 14.5" if including all of the lobes.

Meteorological Plausibility of the Observation

The hailstone fell from a supercell thunderstorm that appeared to be in the process of merging with another cell at the time the large hail occurred. Meteorological conditions supportive of very large hail are indicated in the Storm Prediction Center products given below.

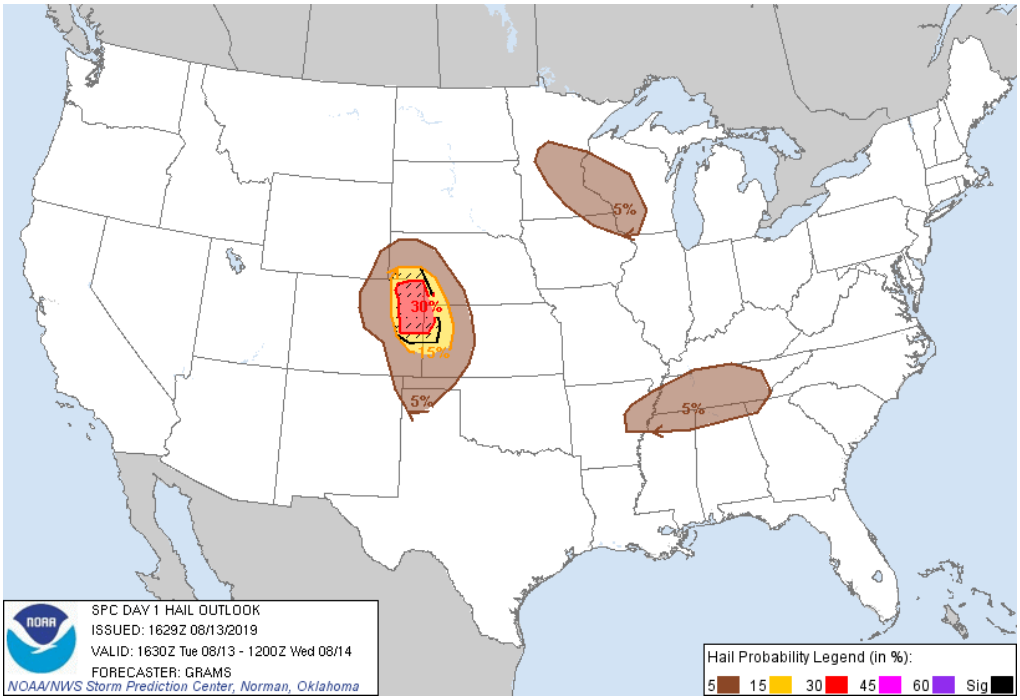
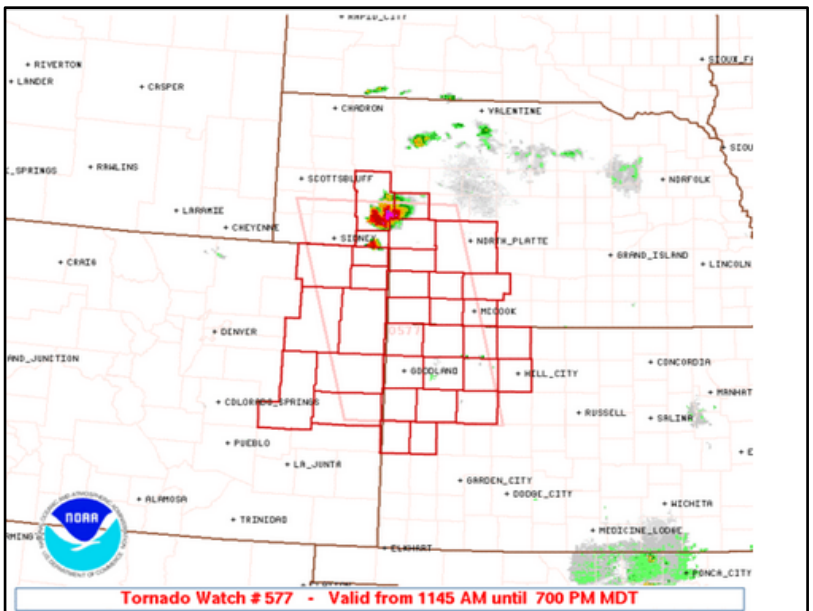


Fig. 6: SPC convective outlook issued at 10:30am local time on 13 August 2019, showing a 30% probability of severe hail, with a "hatched" region indicating a greater than 10% probability of significant (greater than or equal to 2" diameter) hail over northeast Colorado.

From the discussion associated with this outlook (emphasis ours):

> ...Central High Plains...
>
> Weak warm-advection driven convection is ongoing across northwest/north-central NE. To its south, ample low-level moisture is prevalent. The difference between the NAM/RAP in the degree of boundary-layer mixing within the warm/moist sector is unusual in the NAM is actually quite a bit more mixed at peak heating than the RAP (typically its the reverse). Surface dew points will mix to 60-65 F, contributing to a confined corridor of MLCAPE of 2000-3000 J/kg across the CO/KS/NE border area beneath rather steep mid-level lapse rates. Surface-based storm development is expected around 21Z near this tri-state region as convergence strengthens at the intersection of the lee trough and the southward-sagging cold front. **Initial storms will likely be discrete supercells capable of producing isolated very large hail and perhaps a tornado or two.** Convection should grow upscale into a southward propagating cluster into a weak nocturnal low-level jet across far eastern CO/western KS, with a continuing threat for severe wind gusts into early tonight.



Hazard	Tornadoes	EF2+ Tornadoes	Severe Wind	65 kt+ Wind	Severe Hail	2"+ Hail
Likelihood	Moderate	Low	Moderate	Moderate	High	High

SEL7

URGENT - IMMEDIATE BROADCAST REQUESTED
Tornado Watch Number 577
NWS Storm Prediction Center Norman OK
1145 AM MDT Tue Aug 13 2019

The NWS Storm Prediction Center has issued a

* Tornado Watch for portions of
  Eastern Colorado
  Northwest Kansas
  Southwest Nebraska

* Effective this Tuesday morning and evening from 1145 AM until
  700 PM MDT.

* Primary threats include...
  A couple tornadoes possible
  Widespread large hail and scattered very large hail events to 4
    inches in diameter likely
  Scattered damaging winds and isolated significant gusts to 80
    mph likely

SUMMARY...Multiple discrete supercells will pose a risk for
potentially giant hail and a couple tornadoes through this
afternoon. This activity should eventually grow upscale into a
south-southeast moving cluster with an increasing risk for severe
wind gusts towards early evening.

The tornado watch area is approximately along and 70 statute miles
east and west of a line from 50 miles northeast of Sidney NE to 50
miles south southeast of Goodland KS. For a complete depiction of
the watch see the associated watch outline update (WOUS64 KWNS
WOU7).

Fig. 7: Storm Prediction Center Tornado Watch #577, issued at 11:45am local time on 13 August 2019, which mentions "a risk for potentially giant hail."

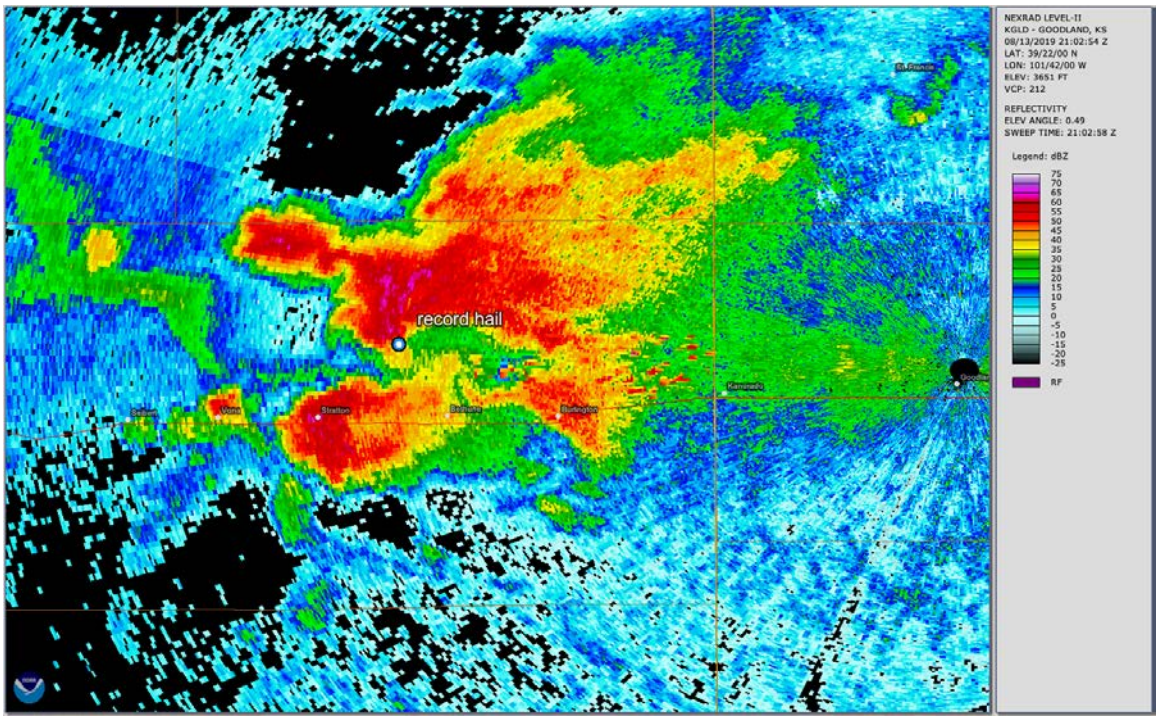


Fig. 8: Radar image from the KGLD radar at 2102 UTC 13 August 2019 (the approximate time of the record-setting hail fall), with the location indicated.

Previous Records

There were no SCEC-established Colorado state records for hail prior to this event. However, hail 4.5 inches in diameter was widely understood by the Colorado Climate Center and others to be the state record. This value was observed multiple times over several decades (Fig. 9). The other dimensions, circumference, weight and volume, did not have established records.

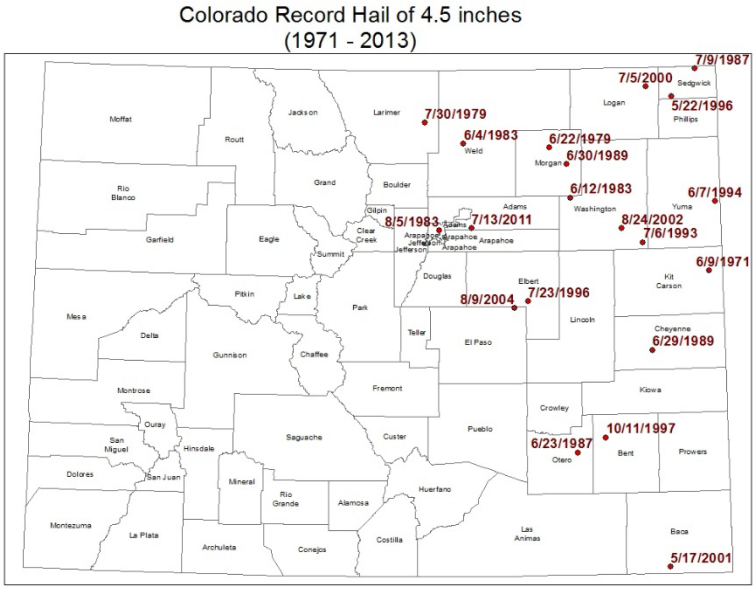


Fig. 9. Locations with 4.5-inch diameter hail reported, known to the Colorado Climate Center via the Storm Data publication. (Courtesy Colorado Climate Center, retrieved 3 October 2019).

Finding of committee

We recognize that larger stones have surely fallen in Colorado, and that sublimation and melting reduced the size of this stone during the time frame of its handling. This very likely accounts for the vast majority of differences between the initial measurements and the 3D-scan-assisted measurements. Additionally, while the 3D-aided circumference is valuable and valid information, and will be reserved in this report, we feel it is more appropriate to consider the smaller "tape measure" method as the record.

Combining these results, we conclude that the following are the best measurements of the hailstone to be established as records for the state of Colorado:

Maximum diameter: 4.83"
Maximum circumference: 12.875"
Mass: 8.5 oz
Volume: 16.549 cubic inches

Committee Members:

- Russ Schumacher, State Climatologist, Colorado Climate Center, Colorado State University
- Tim Kearns, NWS Central Region Cooperative Observer Program Lead
- Natalie Umphlett, Regional Climatologist, High Plains Regional Climate Center
- Grady Bonsall, Acting Meteorologist in Chief, National Weather Service WFO Goodland, Kansas
- Deke Arndt, Chief, Monitoring Section, National Centers for Environmental Information

Additional Committee Participants:

- Becky Bolinger, Assistant State Climatologist, Colorado Climate Center
- David Thede and Brittney Newman, National Weather Service WFO Goodland, Kansas

Technical experts and contributors:

- Ian Giammanco and Ross Maiden (Institute for Business and Home Safety);
- Brian Bledsoe (KKTV, Colorado Springs);
- Andy Heymsfield (NCAR)

Recommendations

When 3D-aided circumferences become more commonplace in the nation's climate record, we recommend that future SCECs reconsider the IBHS measurement.

Acknowledgments

The SCEC thanks the Miltenbeger Family of Bethune, Colorado for the generosity of their time and reporting.

References

Giammanco, I.M., B.R. Maiden, H.E. Estes, and T.M. Brown-Giammanco, 2017: Using 3D Laser Scanning Technology to Create Digital Models of Hailstones. *Bull. Amer. Meteor. Soc*., **98**, 1341–1347, https://doi.org/10.1175/BAMS-D-15-00314.1