

STATE CLIMATE EXTREMES COMMITTEE MEMORANDUM

FROM: Russ Schumacher, Colorado State Climatologist, Colorado Climate Center, Dept. of Atmospheric Science, Colorado State University (SCEC Convener), on behalf of: State Climate Extremes Committee (Schumacher, Stark, Umphlett, Kearns, Gleason)

DATE: 8 May 2020

SUBJECT: Colorado State Mean Sea Level Pressure Record

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Summary

During an intense extratropical cyclone on 13 March 2019, the automated weather station at Lamar, Colorado measured an atmospheric pressure reading at 1716 UTC that, when reduced to mean sea level, was 970.4 hPa¹. Official state records for low pressure have not been kept previously, but after this event, a thorough investigation of available records indicated that this was the lowest mean sea level pressure (MSLP) ever observed in Colorado at a trusted weather station. Based on the evaluation of the available information and evidence, **the SCEC determined the observation of 970.4 hPa to be valid and moved to establish an inaugural Colorado state record for lowest MSLP.**

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 Pueblo, Colorado (WFO Pueblo, which

¹ 1 hectopascal (hPa) is equivalent to 1 millibar (mb).

has warning responsibility for Prowers 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 at <https://www.ncdc.noaa.gov/extremes/scec/details>.

About the Observation

The observation was taken at the NWS Automated Surface Observing Station (ASOS) at Lamar, Colorado. The station is located at the Lamar airport, approximately 3 miles southwest of the city of Lamar in Prowers County, Colorado (Figures 1-2). This ASOS has been in service since 1996. This automated station is located in a region in southeastern Colorado known for rapid cyclogenesis (e.g., Zishka and Smith 1980, *Monthly Weather Review*).

Station metadata (from ACIS):

Station ID: KLAA

Latitude: 38.0700 degrees

Longitude: -102.6881 degrees

Elevation: 3704 feet

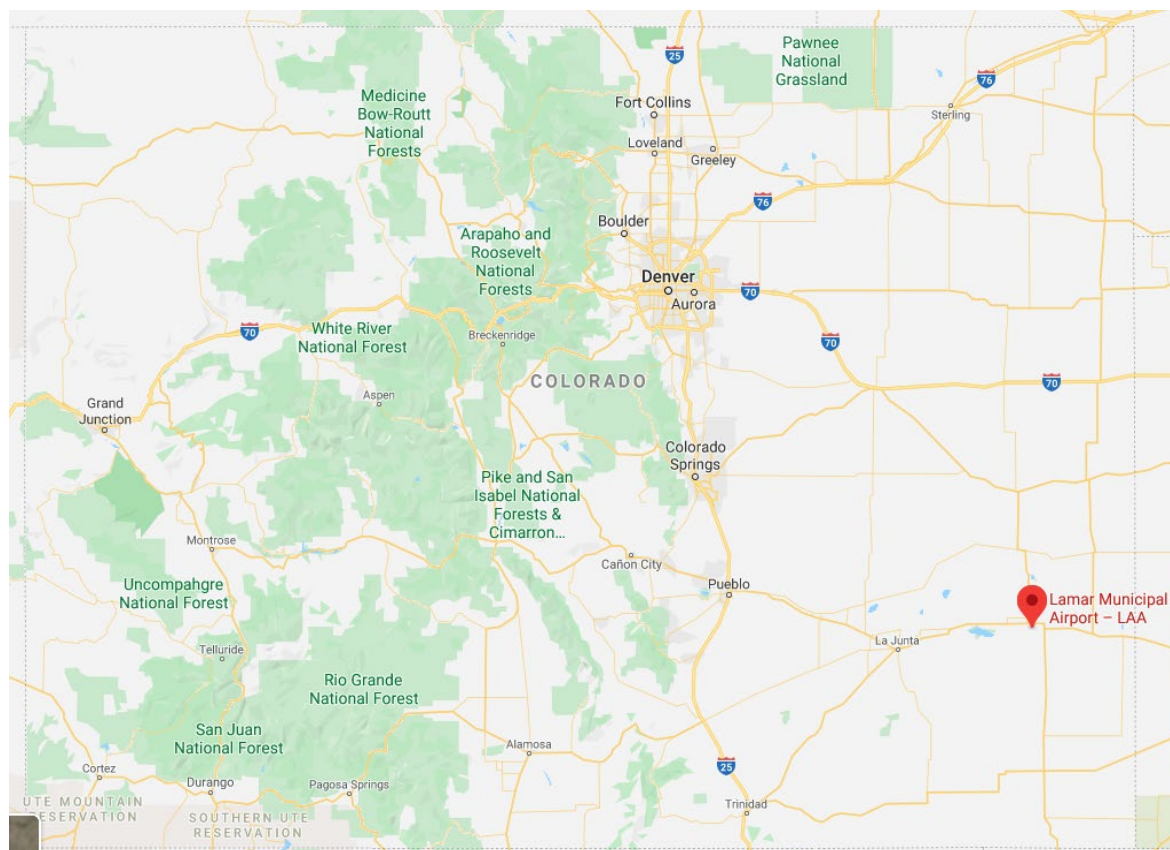


Figure 1: Map of Colorado with Lamar Airport (KLAA) indicated, courtesy of Google Maps.



Figure 2: Photo of the Lamar ASOS, taken 7 May 2020, courtesy Michael Nosko, NWS WFO Pueblo.

Maintenance on the NWS-serviced ASOS equipment is performed regularly, and includes a comparison of values from the three pressure sensors/transducers. The pressure transducers are physically located in the airport terminal building, separately from the main instrumentation suite which collects data for temperature, precipitation, and other elements (Figures 2-3). These sensors undergo hourly quality control to ensure values are consistent and reasonable. There is no documented or known sensor error before, at, or since the time of this potential record. The NWS reports MSLP readings at the top of each hour although sub-hourly values are available internally. The lowest sub-hourly value reported by the NWS WFO Pueblo was 970.4 hPa at 1716 UTC (10:16 am local time) (Figure 4). Officials at the NWS WFO Pueblo indicate that there is no reason to doubt the accuracy of this sub-hourly reading.



Figure 3: Photo of the pressure transducers at the Lamar airport, taken 7 May 2020, courtesy of Michael Nosko, NWS WFO Pueblo.



Lowest observed SLP in S.E. Colorado occurred in Lamar and was measured at 970.4, Altimeter 28.73 #cowx



11:48 AM · Mar 13, 2019 · Twitter Web Client

44 Retweets 73 Likes

Figure 4: Screenshot of KLAJ observations at 1716 UTC 13 March 2019, showing an MSLP of 970.4 hPa, posted to Twitter by the NWS WFO Pueblo.

(<https://twitter.com/NWSPueblo/status/1105888495040692229>)

Meteorological Plausibility of the Observation

A rapidly intensifying extratropical cyclone developed in southeastern Colorado on 13 March 2019, and then moved across the Great Plains. At 1800 UTC 13 March 2019, the NOAA Weather Prediction Center surface analysis indicated that the cyclone had an estimated central pressure of 968 hPa with the center along the Colorado/Kansas border (Figure 5). At this time, the MSLP observation at Lamar was 971.2 hPa; the observation of 970.4 hPa occurred 44 minutes earlier.

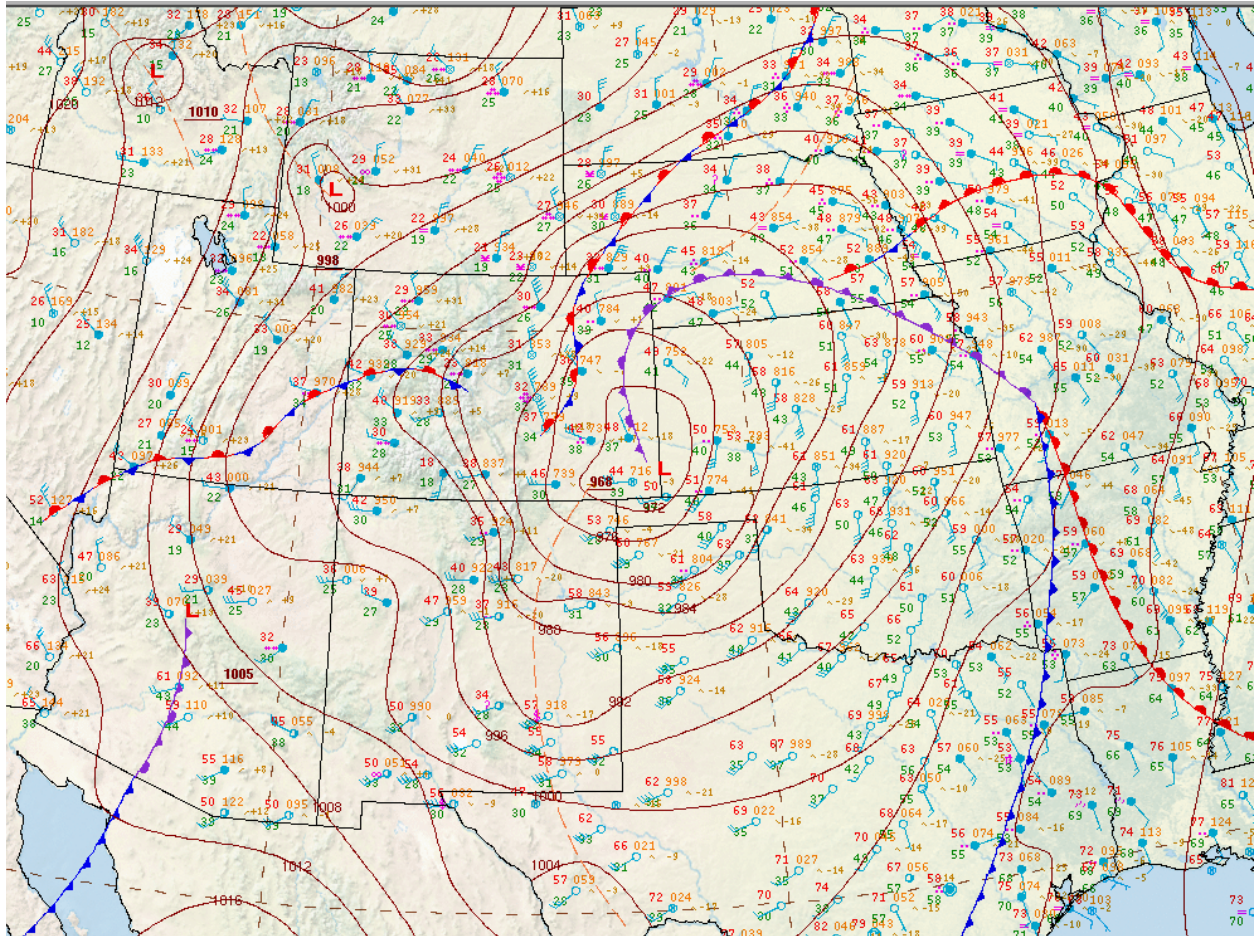


Figure 5: WPC Surface analysis at 1800 UTC 13 March 2019, from <https://www.wpc.ncep.noaa.gov/html/sfc-zoom.php>.

This cyclone brought widespread impacts to eastern Colorado, including blizzard conditions, record wind gusts at several stations, travel disruptions, and a fatal vehicle crash (<https://www.weather.gov/bou/BombCycloneMarch13th2019>). The storm then went on to produce heavy precipitation in Nebraska that led to historic flooding (<https://www.weather.gov/gid/march2019flood> and <https://journals.ametsoc.org/doi/abs/10.1175/BAMS-D-19-0101.1>). This cyclone produced the lowest MSLP on record at numerous stations across eastern Colorado (discussed further in the following section), providing further confidence in the record low pressure observation.

Analysis of historical pressure observations for Colorado

Because there has not previously been an official record low pressure, and historical records of pressure observations are less consistent than for other variables such as temperature and precipitation, numerous methods were employed to identify whether this was the lowest recorded pressure at a station known to be valid.

The primary starting point for identifying possible record-low MSLP is the Weather Prediction Center's analyses of monthly (and all-time) MSLP extremes across the CONUS (<https://www.wpc.ncep.noaa.gov/research/roth/SLPrecords.html>). Prior to the March 2019 storm, this included data (east of the Continental Divide) at Denver, Colorado Springs, Pueblo, and Alamosa, with records at these stations going back to 1893. The lowest value on this map in Colorado was at Denver, 976.3 hPa on 9 February 1960.

The next source of data for identifying low pressure observations was the Iowa Environmental Mesonet (IEM) ASOS archive: http://mesonet.agron.iastate.edu/request/download.phtml?network=CO_ASOS. This archive mainly includes data from the era of automated surface stations (since the mid-1990s), but also includes data going back to the early 1900s for stations that reported hourly surface observations during these time periods. The details of this analysis are included in Appendix A, but the 29 lowest MSLP observations in Colorado in this database for Colorado occurred on 13 March 2019. The lowest in the database was from KCWN (Cheyenne Mountain): 970.2 hPa at 1058 UTC 13 March 2019. However, this observation is suspect because no further data were reported from this station on this day (i.e., all data were missing after the time of this observation), and the reported MSLP at this station was consistently 5-10 hPa lower than all other stations in the area (Appendix A). According to NWS WFO Pueblo, this is a station on a military installation and is not maintained by the NWS. Therefore, given these uncertainties, we have rejected this data point from the analysis.

The next lowest in the IEM database was 971.0 hPa at KLAA (Lamar) at 1653 UTC 13 March 2019. As noted above, NWS WFO Pueblo confirmed that the MSLP at KLAA reached 970.4 hPa at 1716 UTC. KLAA reported numerous other MSLP observations below 973.0 hPa, as did other stations in southeastern Colorado on 13 March 2019 (Figure 6), further confirming the low pressures in this event. Based on this analysis, the observation of 970.4 hPa is the lowest MSLP observed (at a station known to be valid) in the 13 March 2019 storm.

Further analysis of historical storms using the NOAA 20th century reanalysis and other observations is reported in Appendix A; no observations of pressure as low as the 13 March 2019 storm were found, **and these analyses lead us to conclude that the observation of 970.4 hPa at Lamar on 13 March 2019 is the lowest MSLP observed at a station known to be valid in Colorado state history.**

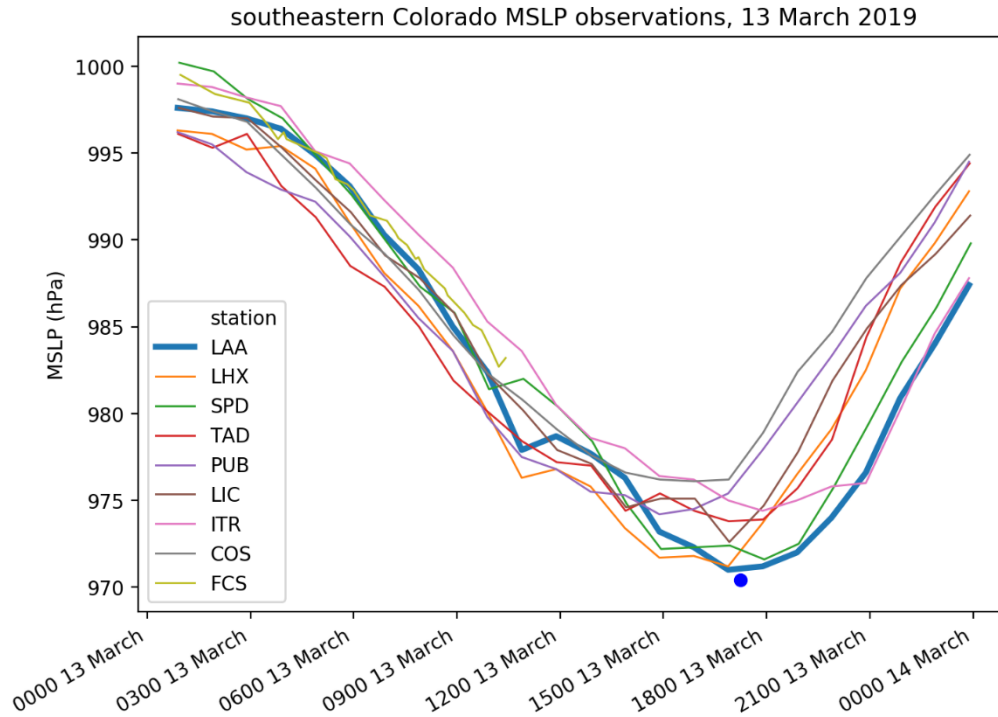


Figure 6: Time series of MSLP from several NWS ASOS stations in southeastern Colorado on 13 March 2019. Hourly observations are plotted with lines; the sub-hourly observation of 970.4 hPa at KLAA is shown with the blue circle.

Caveats and limitations

This record is established for MSLP, as opposed to station pressure. Station pressure is a strong function of station elevation, so especially in locations with complex terrain (like Colorado), it is important to adjust the pressure to a reference elevation (in meteorology, mean sea level is typically used) to identify pressure differences that are reflective of meteorological conditions as opposed to simply terrain gradients. However, methods used to adjust from station pressure to MSLP make assumptions about the atmospheric profile and are subject to limitations (https://www.weather.gov/bou/pressure_definitions). Nonetheless, Appendix A includes a comparison of station pressure to MSLP for southeastern Colorado that further supports the idea that the low pressure values on 13 March 2019 were indeed record values and are not simply caused by the MSLP adjustment.

We also acknowledge that this value is likely **not** the lowest MSLP value in Colorado's history. Reliable pressure-measuring instruments gather information from a small percentage of the state's geography, which will undoubtedly leave room for not being able to identify even lower values than what is officially measured. We also acknowledge that pressure readings measured from within tornadoes would likely be considerably lower than any observed synoptic value, but we are unaware of any such observations at established weather stations in Colorado.

Finding of committee

Based on examination of data from the 13 March 2019 cyclone and a thorough investigation of historical pressure records in Colorado, this committee concludes (by a 5-0 vote) that the MSLP of 970.4 hPa observed at Lamar, Colorado should be established as the inaugural record low MSLP for Colorado.

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
- Jennifer Stark, Meteorologist in Charge, National Weather Service WFO Pueblo, Colorado (at the time this event occurred; currently MIC at NWS WFO Boulder, Colorado)
- Karin Gleason, Meteorologist, National Centers for Environmental Information

Additional Committee Participants:

- Deke Arndt, Chief, Monitoring Section, National Centers for Environmental Information
- Becky Bolinger, Assistant State Climatologist, Colorado Climate Center
- Michael Nosko, Observation Program Lead, NWS WFO Pueblo
- David Roth, Lead Meteorologist/Forecaster, NOAA/NWS Weather Prediction Center
- Michael Anderson, California State Climatologist

NCEI Climate Monitoring Chief Decision:

Approved

as recommended in boldface above:

Not approved

returned to SCEC with no action taken:

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Acknowledgments

The SCEC thanks the NWS WFOs in Pueblo and Boulder for their contributions to collecting and analyzing data from the 13 March 2019 cyclone and David Roth of NOAA/NWS/WPC for his thorough analyses of historical pressure observations that guided much of this process.

Appendix A: Further information about past low MSLP observations in Colorado

Russ Schumacher, Colorado State Climatologist, spring 2020

To begin, it is important to note the reasons for examining mean sea level pressure (MSLP) as opposed to station pressure. Station pressure is a strong function of station elevation, so especially in locations with complex terrain (like Colorado), it is important to adjust the pressure to a reference elevation (in meteorology, mean sea level is typically used) to identify pressure differences that are reflective of meteorological conditions as opposed to simply terrain gradients. However, we will show a comparison between MSLP and station pressure at one station to identify whether the assumptions in the MSLP correction are influencing the conclusions.

The primary starting point for identifying possible record-low MSLP is the Weather Prediction Center's analyses of monthly (and all-time) MSLP extremes across the CONUS (<https://www.wpc.ncep.noaa.gov/research/roth/SLPrecords.html>). Prior to the March 2019 storm, this included data (east of the divide) at Denver, Colorado Springs, Pueblo, and Alamosa, with records at these stations going back to 1893. The lowest value on this map in Colorado was at Denver, 976.3 hPa on 9 February 1960.

The next source of data for identifying low pressure observations was the Iowa Environmental Mesonet (IEM) ASOS archive: http://mesonet.agron.iastate.edu/request/download.phtml?network=CO_ASOS. This archive mainly includes data from the era of automated surface stations (since the mid-1990s), but also includes data going back to the early 1900s for stations that reported METAR observations during these time periods.

I collected all MSLP observations at Colorado stations that were available in this archive.² Two stations had pressure data that were frequently in error: KEGE (Eagle) and KABH (a USAFA auxiliary airfield in Ellicott, CO). These stations were removed from analysis. The decoding of METAR observations in the IEM archive also included SLP data that were erroneously decoded, when the station pressure was very high (for example, METAR including SLP552 that was decoded as 955.2 hPa, but was almost certainly 1055.2 hPa in reality). These were situations with very low temperatures and very high station pressures and altimeter settings. Thus, I required the altimeter setting to be lower than 30.25 inches, and the SLP to be greater than 955.0 hPa (since there was no indication of any valid SLP observations lower than 955.0 hPa; such values are not meteorologically realistic for Colorado).

After these steps, the lowest remaining pressures were in the 955-960 hPa range, mainly from KALS, KPUB, and KCOS in the 1960s. These observations generally had low altimeter settings but also extremely low temperatures (below -10°F), suggesting they were likely associated with very high rather than very low pressure (and were thus also decoding errors). Many of these observations were on 10 January 1962, which is indeed recognized as the all-time record *high* pressure for Colorado Springs, Denver, and Pueblo (see the WPC pressure records page). Thus, these were also removed from the analysis. Several observations remained from KFCS (Fort Carson) that were further investigated and found to be in error - the MSLP observations fluctuated wildly on these days and were not consistent with nearby observations.

² Python code used for this analysis is available upon request.

Of the remaining lowest MSLP observations, the top 29 were all from 13 March 2019, all of them below 975.0 mb. The lowest in the database was from KCWN (Cheyenne Mountain): 970.2 hPa at 1058 UTC 13 March 2019. However, this observation is suspect because no further data were reported from this station on this day (i.e., all data were missing after the time of this observation), and the reported MSLP at this station was consistently 5-10 hPa lower than all other stations in the area (Figure A1). According to NWS WFO Pueblo, this is a station on a military installation and is not maintained by the NWS. Therefore, given these uncertainties, we have rejected this data point from the analysis.

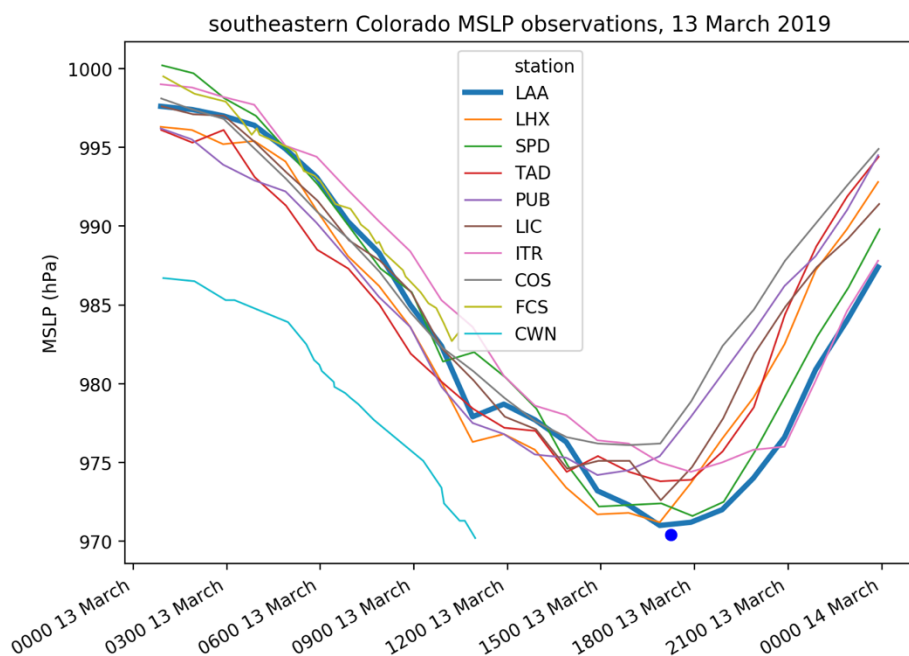


Figure A1: Same as Figure 6, except including observations from KCWN (cyan), which were consistently much lower than all other nearby stations.

The next lowest in the IEM database was 971.0 hPa at KLAA (Lamar) at 1653 UTC 13 March 2019. NWS WFO Pueblo confirmed that the MSLP at KLAA reached 970.4 hPa at 1716 UTC (see <https://twitter.com/NWSPueblo/status/1105888495040692229/photo/1>). (Note that MSLP is not typically reported in sub-hourly METARs, but NWS offices have access to these observations.) KLAA reported numerous other MSLP observations below 973.0 mb, as did other stations in southeastern Colorado on 13 March 2019, further confirming the low pressures in this event. **Thus, this value of 970.4 hPa is the lowest MSLP observed (at a station known to be valid) in the 13 March 2019 storm.**

A few additional methods were employed to identify other events in which the pressure may have been especially low across eastern Colorado. One was an interrogation of NOAA's 20th Century Reanalysis version 3 (20CR; obtained from <https://rda.ucar.edu/datasets/ds131.3/>), a long-term reanalysis (1835-2015) based primarily on surface pressure observations. I searched for instances where the MSLP in the 20CR was lower than 977.5 hPa within Colorado.³ This reanalysis has fairly coarse spatial resolution (approximately 0.7° lat/lon) so is unlikely to identify local extremes, but is an objective way to identify cases worthy of further investigation. This turned up five storms which were investigated further:

³ Python code used for this analysis is available upon request, as are maps of MSLP for events mentioned in the text.

- 21 April 1883 (20CR minimum MSLP: 974.27 hPa at 1500 UTC)
- 26 March 1950 (20CR minimum MSLP: 974.37 hPa at 1500 UTC)
- 9 February 1960 (20CR minimum MSLP: 977.25 hPa at 1200 UTC)
- 14 March 1973 (20CR minimum MSLP: 975.11 hPa at 0300 UTC)
- 1 February 1982 (20CR minimum MSLP: 977.35 hPa at 2100 UTC)

Pressure observations are more limited for many of these storms, but some observations were available for each storm.

For 21 April 1883, paper records of the station at West Las Animas in southeast Colorado showed a minimum MSLP of 28.885 inches, which converts to 978.5 hPa. The NWS Daily Weather Map also shows this observation and has the surface low analyzed below 28.9" (978.6 hPa).

For 26 March 1950, the Local Climatological Data (LCD) was obtained from NCEI for La Junta; the only station in southeastern Colorado with reliable data (that was not already included in other sources like WPC's archives) available for this event. The minimum MSLP was 28.84 inches at 0400 UTC 26 March 1950, which converts to 976.6 hPa.

For 9 February 1960, note that this was the same storm at which the Denver low-pressure record of 976.3 hPa was set. The La Junta LCD was similarly obtained for this event, and the lowest MSLP was 28.93" or 979.6 hPa; this is higher than the Denver value.

For 14 March 1973, more MSLP observations were available. This was an intense cyclone that set some single-station records for low MSLP in Nebraska and Kansas. In the IEM archive, the lowest sea level pressure found from this storm was 975.8 hPa at La Junta. Furthermore, an MSLP of 975.0 hPa was found in another IEM archive of GEMPAK surface data (<https://mtarchive.geol.iastate.edu/>) at station K4LJ, a now-defunct station at the Lamar airport, at 0000 UTC 14 March 1973. Before the March 2019 storm, this value of 975.0 hPa was likely the lowest observed MSLP in Colorado.

Unfortunately, because the 20CR only goes through 2015, it is not possible to get an 'apples-to-apples' comparison of how the 20CR would have analyzed the MSLP in the March 2019 cyclone, but this investigation provides further confidence that there are not historical storms that are being missed here.

One remaining question is regarding uncertainties in the methods used to correct station pressure to sea level pressure; these methods make assumptions about the vertical structure of the atmosphere that may introduce errors in extreme situations and in complex terrain. However, we cannot compare station pressures at different stations (because of their different elevations), so these comparisons must be made at a single station. To examine this issue, the LCDs for La Junta were also analyzed going back to 1942 (again, this is the one station on the eastern Plains with long-term data that was not included in WPC's records). Unfortunately, station pressures are not recorded at all dates/times in the LCDs either, but there are many observations to consider.

The lowest **station pressure** at La Junta prior to March 2019 was found to be 24.76" on 26 March 1950; the minimum MSLP on this day was 28.84" (976.6 mb). No station pressures were reported at La Junta during March 1973, but the lowest MSLP in the LCD was 28.82" (975.9 mb). On 13 March 2019, the lowest station pressure at La Junta was 24.64" and lowest MSLP was 28.68" (971.2 mb). Both of these values are considerably lower than any of the values previously reported at La Junta, which provides further confidence that they are the lowest on record at this station, and accordingly that the March 2019 storm had the lowest pressures on record for Colorado.

All of these analyses lead us to conclude that the observation of 970.4 hPa at Lamar on 13 March 2019 is the lowest MSLP observed at a station known to be valid in Colorado state history.

One caveat to this analysis is that the pressure may have been locally lower at the centers of strong tornadoes; these small-scale variations are extremely difficult to observe unless the tornado passed directly over an established weather station. We are unaware of any such observations within Colorado.