



The Arctic Plunges South: The Meteorology Behind the Historical Event

Arctic outbreaks across the southern plains are not too uncommon with a cold push typically seen once or twice a year. They are typically short-lived as the pattern for cold weather is usually in and out within a span of a few days as cold air rushes in with a strong cold front, then vacates as high pressure involved pushes east. Texas sees several cold fronts each winter with the coldest air typically in January or February when cold air to the north builds up in conjunction with snow pack in the plains of Canada and the US. Historically, Texas sees a significant cold outbreak once every decade that sends the state into a deep freeze for a time before warming back up and returning to normal. This past winter was littered with high impact winter events for the state, especially for areas west of I-35 as a historic snow and ice event unfolded right before the turn of the calendar year.

February began as a pretty mundane month with temperatures near to actually above-normal for the first 10 days. In fact, at Midland International Airport, we set a daily record high of 83°F on February 3rd, only surpassed by a few dates on the earliest time frame for reaching a temperature of 83 degrees or higher. The entire Southwest US was under a strong upper-level ridge that helped create a warm, temperate environment with above-normal temperatures in the lowest levels in the atmosphere. The



pattern upstream still wasn't super complex with a large ridge building over the northern Pacific, extending into Alaska. This pattern didn't necessarily have the typical look of a potential historical outbreak of cold, but the trend continued to favor much colder conditions in the following days as the pattern evolved.

By the end of the first week of February, computer models were hinting at a sharp transition of the pattern across the Lower 48 of the US with an amplifying trough across the northern plains, extending down into areas east of the Continental Divide (Rocky Mountains). Forecast temperatures at range were really impressive on computer models with some gaudy numbers being printed out for our area of Texas. At range, you don't really think much of it because a lot of times these numbers don't pan out and the model shifts its focus away from West Texas and we get hit with a glancing blow. There was one aspect of this forecast that was sticking out, however, and it's traditionally something that alludes to a potential arctic outbreak for Texas.

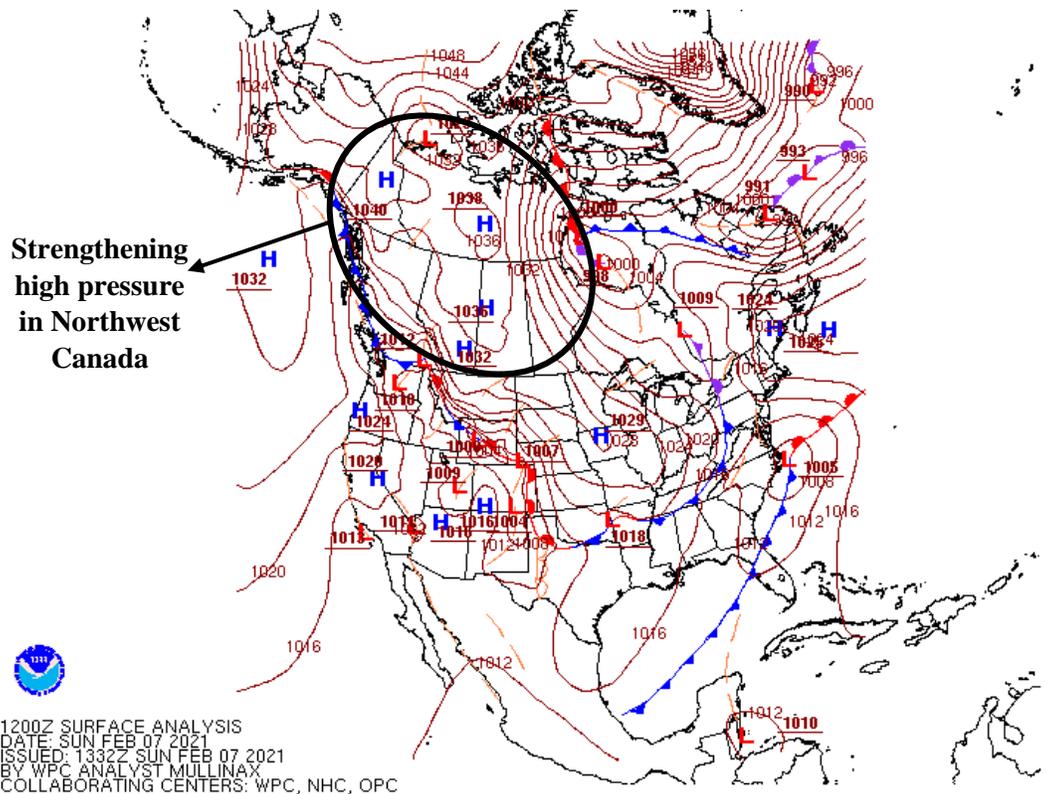


Leading up to February 7th, a strong surface high pressure really began putting its staple on areas along and north of I-40 with incredible cold temperatures spilling into areas of Kansas up into the northern plains. The high pressure had roots all the way back to arctic Canada with temperatures as low as -50°F nestled into the Yukon territory. This was the source region of the cold

entering the US, so it was something to take note of because the depth the cold in terms of latitude was creeping into our area of the country.

Anymore of a push would place our

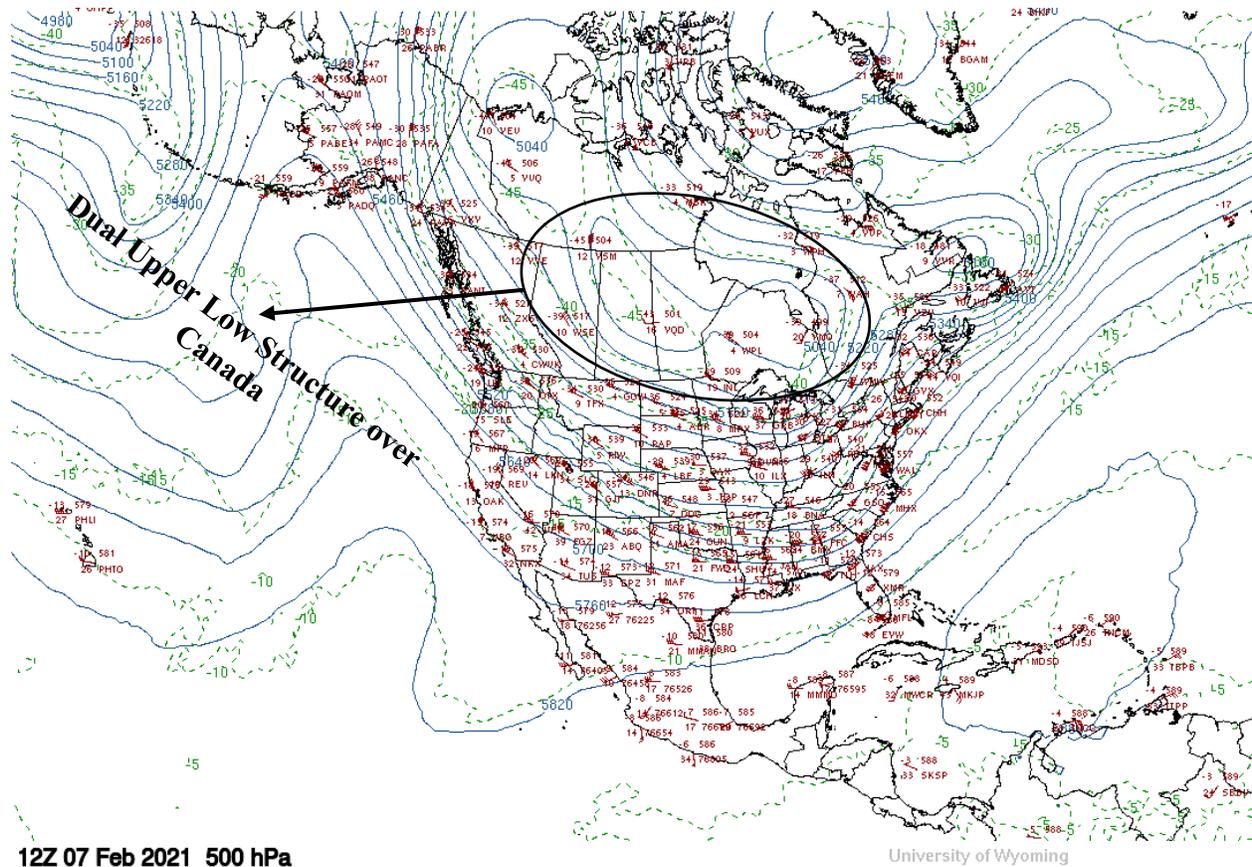
spot in West Texas under the hood of some pretty fierce arctic air that would send the region into the freezer. A lot of what occurs at the surface is driven by what happens aloft, which is why we talk about the trough and ridge patterns over the US. This setup was no different, and in fact had a major part of what was unfolding.



Surface Analysis on Feb 7th, 2021 at 12z. High pressure over Northwest Canada outlined. Source: Weather Prediction Center



On the morning of February 7th, the upper-air analysis provided by data from satellite and atmospheric soundings (weather balloons) showed a distinct area of elongated troughing with dumbbelling upper-level lows over the southern tier of Canada. Incredibly, cold air was being displayed under the upper-lows which is important to analyze for magnitude of the cold. The alignment of the trough with the lows in tandem created the beginning of something in meteorology called the *McFarland signature*.

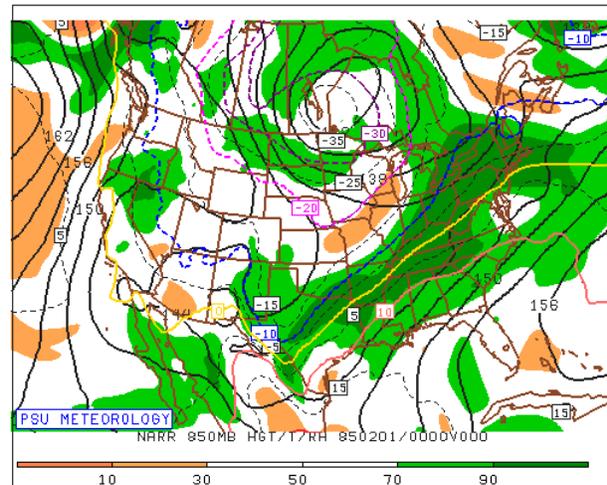
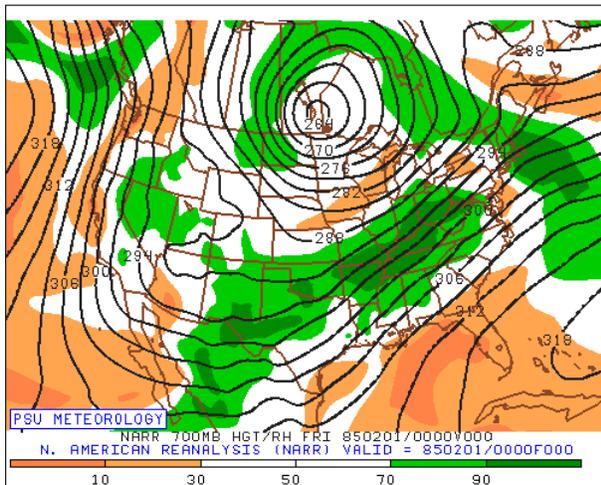
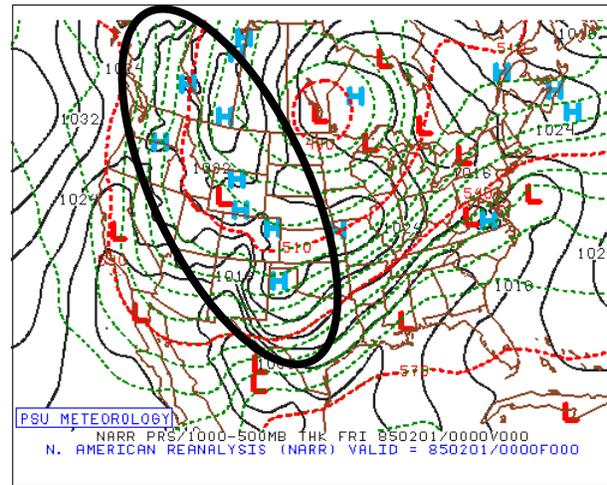
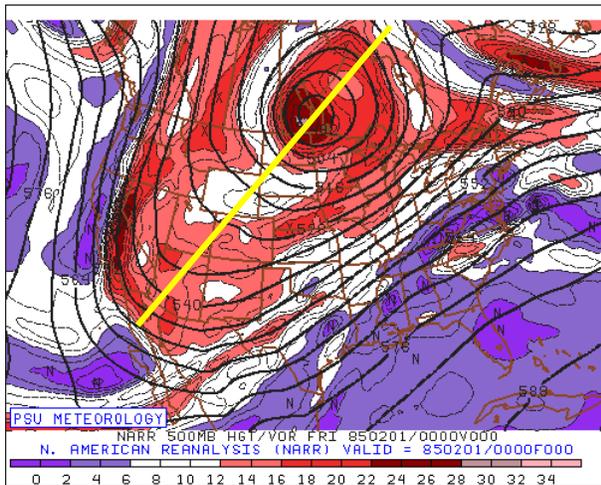


Upper Air Analysis on Feb 7th, 2021 at 12z. Source: Univ. of Wyoming

Back into the mid-1970's, meteorologist Marshall J. McFarland of Texas A&M University studied multiple arctic outbreaks for the Rio Grande Valley in earlier history in hopes to find a key in



forecasting for severe cold down into Deep South Texas. The noted freezes of the past all had a similar upper-level “signature” of elongated troughing that extended west to east with a deep polar vortex displaced over Southern Canada. The trough extension and positioning would allow a strong anti-cyclone (high pressure) to develop across Western Canada, and bridge down into the lower latitudes of North America. In order to get significant cold air into South Texas, there has to be a mechanism to get that level of cold into what is typically the northern fringes of the tropics. A well-defined upper pattern as mentioned above would allow for arctic cold to spill into the US with a further south progression pending how far south the elongated trough axis would protrude (For more information on the McFarland signature, please see [McFarland Signature Example](#)). This is why we at the National Weather Service in Midland were becoming more concerned with the upcoming setup. Looking back into the archives revealed this signature was responsible for a vast majority of our arctic outbreaks seen in West Texas. The guidance for the forecast were having carbon copies of the same setups that produced some of the coldest outbreaks in the history of Midland (1962, 1973, 1983, 1985, and 2007). Many of those outbreaks were not one- or two-day long events, but several days of temperatures never breaching freezing. The coldest day ever recorded in Midland was on the morning of February 2nd, 1985 when Midland reached down to -11°F. So, despite history saying it’s incredibly rare, we had model data backing up the premise to the outbreak.

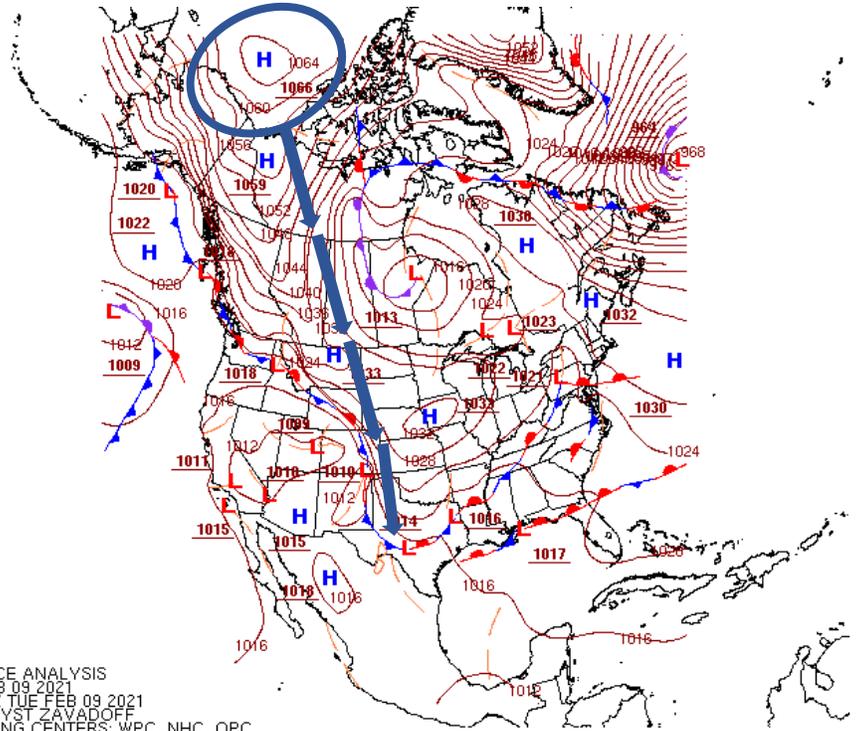


Reanalysis of the Feb 1st, 1985 Arctic outbreak. Upper Left: 500mb panel at 12z 2/1/85 showing the elongated trough tilting back west, a strong indication of arctic air back to the southern plains. Upper Right: Surface panel outlining the high pressure building south into the south plains. Source: Pennsylvania State Univ. Meteorology

By the morning of the 9th, it was apparent what was about to unfold; a sustained period of cold that hasn't been seen in decades. Our upper-air pattern was ripe and textbook for the cold push to descend further south into the heart of the southern plains. An earth shattering 1066mb high pressure was analyzed over the Arctic circle extending down through Western Canada with a wedge of anomalously cold air filtering south into the



Northern Rockies and plains. The leading edge of the cold was beginning to make headway into the Permian Basin as temperatures in the 30s and 40s were common along the northern tier of counties in wake of the cold front. Forecast highs for the follow days were much colder, however, and the long period of cold was just beginning for West Texas. By the 10th and 11th, the cold was gripping pretty much everywhere north of the Davis Mountains, extending east into the rest of the Lonestar state. Our surface high was gradually sinking south with a stout cold air advection pattern (advection occurs when something is moved by wind, so northerly winds “advecting” cold into the area). A few thousand feet above the surface, winds were actually still out of the west and southwest as the southern tier of the US was still under a zonal wind pattern aloft (zonal occurs when winds move west to east). Since the cold air was so shallow compared to above, the deep cold undercut the warmer



1200Z SURFACE ANALYSIS
DATE: TUE FEB 09 2021
ISSUED: 1612Z TUE FEB 09 2021
BY: WPC ANALYST ZAVADOFF
COLLABORATING CENTERS: WPC, NHC, OPC

Surface Analysis on Feb 9th, 2021 at 12z. Circled: Center of the 1066mb high pressure that moved in from Siberia (Russia). High pressure nosed down the front range of the Rockies, sending Arctic air southward (Noted by arrows). Source: Weather Prediction Center

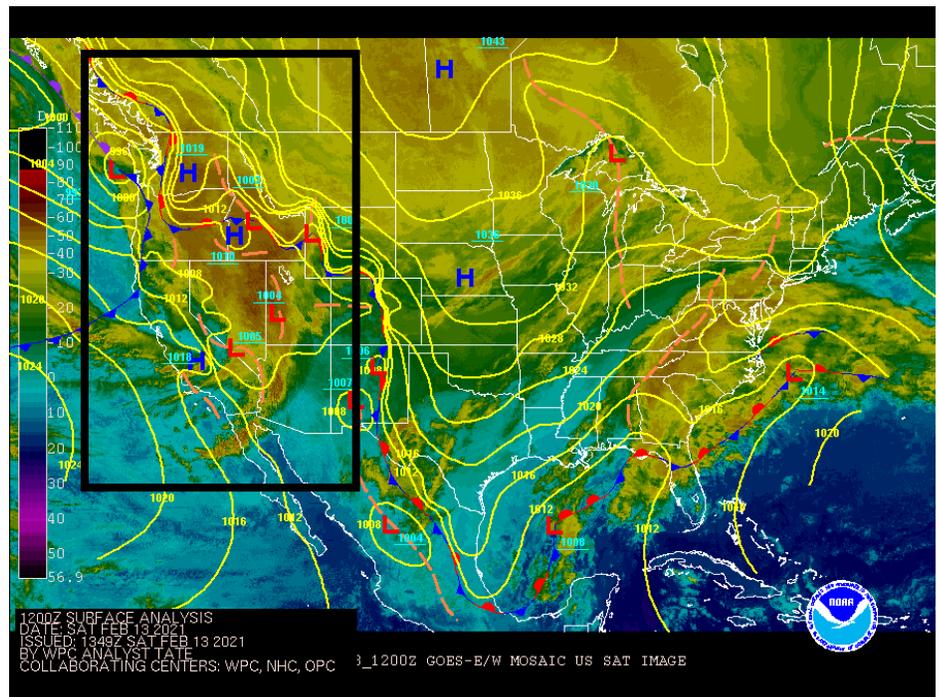


air causing a shallow layer of lift across the lower boundary layer. This generated a swath of low clouds and persistent drizzle into sub-freezing air, creating a prolonged icing event in areas of West Texas. The Northern Permian Basin was the highest impacted area in the early stages of the arctic outbreak as sub-freezing temperatures locked in across places like Snyder/Gail/Lamesa by the morning of the 11th.

This pattern would slowly extend south over the next few days with areas along the I-20 corridor getting into the persistent freezing drizzle, fog, and mist which created a deep winter landscape over the high desert of Texas. While this was a continuing problem for a section of the forecast area, this was just the tip of the iceberg meteorologically as future forecasts were continuing to hammer the cold deeper into the region with a potential snowstorm brewing on Valentine's Day. Out in the Eastern Pacific, a low-pressure system was making its way southeast into the Pacific coast of Oregon and Northern California as it slid under the ridge placed across the Northern Pacific. This is an added disruption to the current pattern as the cold push was enough to send the area into a crippling state from the ice and eventual snow building up on roads, trees, and



powerlines. With the sustained cold thanks to the strong arctic high to the north, a low-pressure system trekking eastward across the Four Corners would provide significant lift favoring areas like New Mexico and West Texas. Considering the evolution of the storm, heavy snow, strong winds with dangerous wind chills, and crippling impact to travel were all in the works for areas impacted.



Surface/Satellite composite on Feb 13th, 2021 at 12z. Circled: Storm system entering the Western US with precipitation breaking out over the Northern Great Basin. Source: Weather Prediction Center

By the 13th, brutal cold with highs in the teens were now in place for much of West Texas east of the Davis Mountains. A core of the cold from the Northern Plains had officially made it south into Texas with highs in the single digits common for the Panhandle up near Amarillo. Snow began to break-out to the west over New Mexico as our low pressure started meandering to the north of the Four Corners area. Aided by a strong upper-level jet streak out west, the forcing necessary to generate an encompassing area of precipitation was well-established. By the morning of Sunday, the 14th, West Texas was in the crosshairs

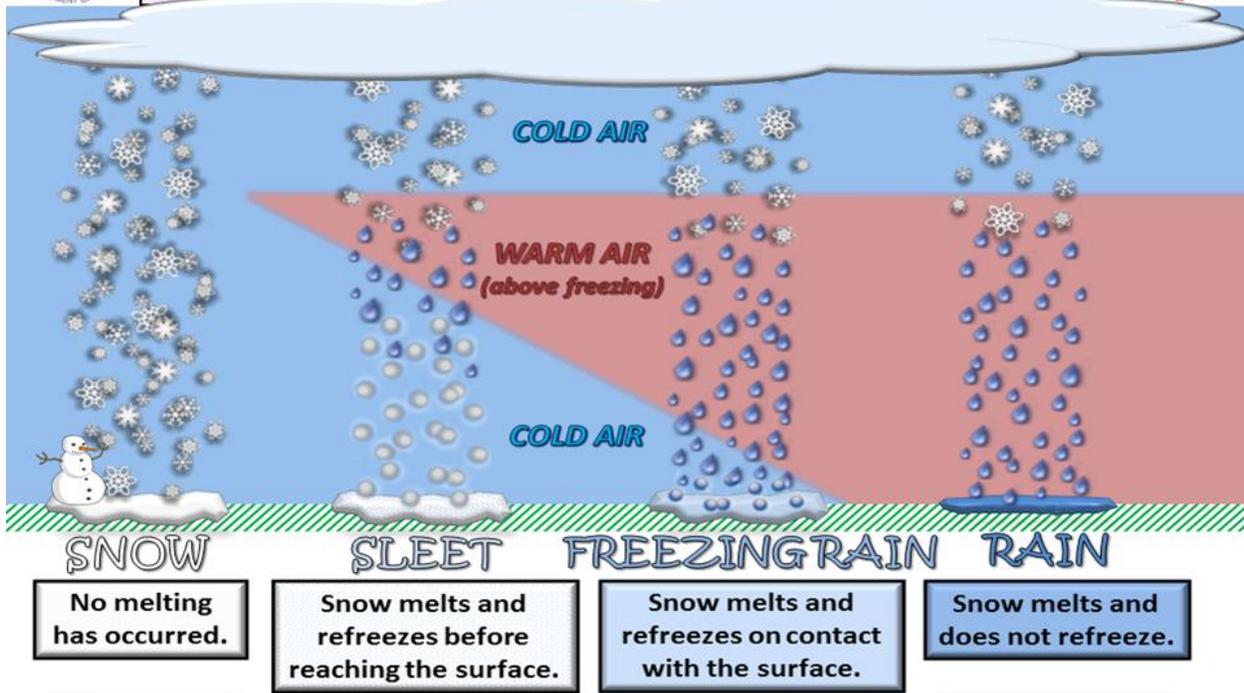


for a winter blitz that has not been seen for several decades. In fact, historical records have only shown snow falling at the forecasted temperatures in the single digits on Sunday afternoon one other time in recorded history; that famed period in early February of 1985.

The difference in this setup was the magnitude of snow and the mechanism behind the snow and cold. In February of 1985, the snow was caused by a sharp arctic front that blasted through the area with accompanying snow squalls that painted the area in white. This storm was an organized low-pressure system that traditionally causes the larger snowfalls for the region, and some of the most disruptive weather during winter time. As the trough out west pivoted eastward, colder air aloft would break through the warm tongue of air above the surface that prevented a lot of the precipitation earlier in the outbreak from being snow. This was necessary for a continued snowfall as this changed the atmospheric thermodynamic structure (temperatures) necessary for a change from liquid precipitation to ice crystals. As the trough moved into New Mexico with the best forcing focused over West Texas, periods of heavy snowfall and strong winds began to bring a true flavor of the arctic to Texas. Temperatures plummeted behind a surge of very cold air mixing to the surface as colder temperatures aloft were able to penetrate deeper into the lower boundary layer. In layman's terms, colder air aloft began funneling down towards the surface during snowfall. With the heavier snowfall, temperatures in the teens eventually fell into the single digits.



Winter Precipitation



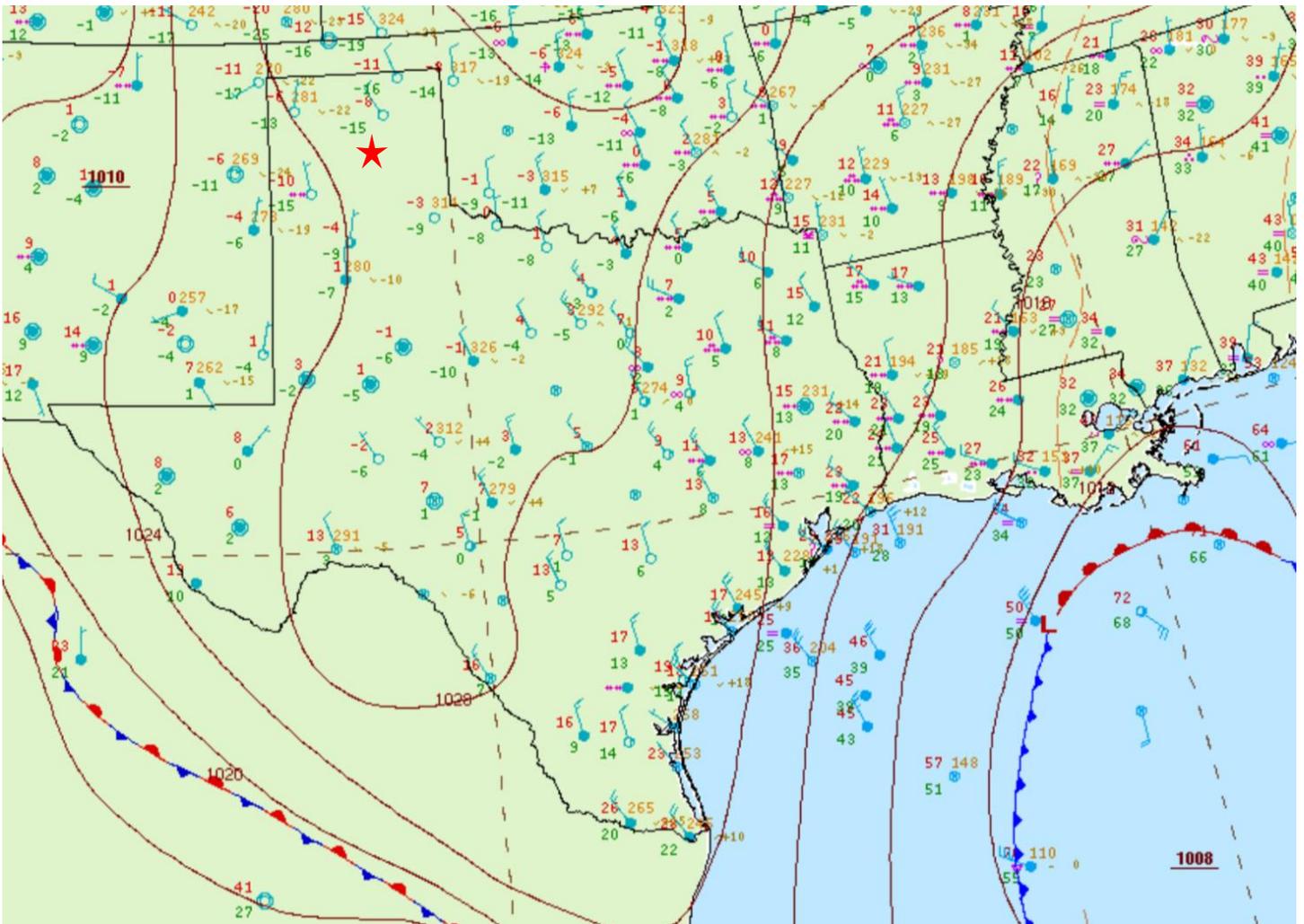
	NWS Northern Indiana www.weather.gov/iwx		/US.NationalWeatherService.NorthernIN.gov
			@NWSIWX /NWSNorthernIndiana

Diagram showing how the depths of warm and cold air aloft to the surface play a pivotal role in precipitation type during winter weather. As the air aloft gets colder with already below freezing air at the surface, any liquid turns to all frozen, eventually all snow when all levels are below-freezing. Source: National Weather Service (Northern Indiana)

By the night of the 14th, our low-pressure center had weakened as it exited the mountain west, but a secondary low developed in the Western Gulf to allowing further precipitation across the eastern half of Texas. Strong high pressure nosed south into the western half of the state leading to lighter winds and deep cold centering from Amarillo down into the Western Hill country, back to the Davis Mountains. By the morning of the 15th, temperatures were below zero for about 30% of the state and over 75% of the state was below 20°F. Only the cold outbreaks



of 1962 and 1983 had this magnitude of arctic cold across the Lone Star state in recent memory. Our deep upper trough that helped propel this outbreak had dug south into Texas, leading to the coldest air settling over the southern plains.



High resolution surface analysis over the southern plains at 12z February 15th, 2021. Temperatures over Texas ranged from -20°F over the interior portions of the Northern Panhandle (Red Star: Palo Duro Canyon Reservoir Mesonet) to near 30°F near the Gulf Coast. Every square mile in Texas was below-freezing for the first time since the Great Arctic Outbreak of 1962. Source: Weather Prediction Center



Highs on the 15th would struggle to even reach the teens with Midland International capping at 15°F for the afternoon. This high temperature would end up being the second coldest daily maximum temperature for the month of February on record. Thanks to a blocking pattern over Maritime Canada, the trough responsible was very slow to breakdown, allowing for a prolonged stretch of below normal heights aloft. This contributed to cold air lingering for days behind our big storm, causing a plethora of issues in its wake.

Another disturbance would slide to the north by mid-week with one last cold front making waves into West Texas. This put the seal on a 14-year record of the longest time frame below 32°F for the Midland area. In fact, the new record of 8 days below freezing would shatter the old record of 5 days set back in 2007. Areas such as Snyder had a longer spell within our forecast area since their temperatures sunk below freezing hours before Midland, which is the official climate site for West Texas. By the 18th of February, high pressure to the north finally motioned to the east with a return of southerly winds and warmer air moving back overhead. With temperatures in the 40s and 50s areawide, the area felt like the tropics after the previous week-plus of unrelenting cold. Snow cover lasting almost a week is unfathomable in these parts, but it happened. The lingering impact of the event would be felt for months as structural damage due to the ice and snow would pay dividends on the overall infrastructure of West Texas.



Climatological Data for MIDLAND INTERNATIONAL AP, TX - February 2021

Click column heading to sort ascending, click again to sort descending.

Date	Max Temperature	Min Temperature	Avg Temperature	Avg Temperature Departure	HDD	CDD	Precipitation	Snowfall	Snow Depth
2021-02-01	62	28	45.0	-2.4	20	0	0.00	0.0	0
2021-02-02	75	43	59.0	11.4	6	0	0.00	0.0	0
2021-02-03	83	42	62.5	14.7	2	0	0.00	0.0	0
2021-02-04	70	44	57.0	9.1	8	0	0.00	0.0	0
2021-02-05	66	30	48.0	-0.1	17	0	0.00	0.0	0
2021-02-06	64	38	51.0	2.7	14	0	0.00	0.0	0
2021-02-07	75	35	55.0	6.5	10	0	0.00	0.0	0
2021-02-08	77	45	61.0	12.3	4	0	0.00	0.0	0
2021-02-09	57	28	42.5	-6.4	22	0	0.00	0.0	0
2021-02-10	36	25	30.5	-18.6	34	0	T	0.0	0
2021-02-11	29	22	25.5	-23.8	39	0	T	T	T
2021-02-12	27	18	22.5	-27.0	42	0	0.01	T	T
2021-02-13	20	15	17.5	-32.2	47	0	0.04	0.3	T
2021-02-14	17	5	11.0	-38.9	54	0	0.11	5.3	1
2021-02-15	15	-2	6.5	-43.6	58	0	T	T	5
2021-02-16	29	4	16.5	-33.8	48	0	T	0.0	2
2021-02-17	24	14	19.0	-31.6	46	0	T	T	2
2021-02-18	22	9	15.5	-35.3	49	0	T	0.0	2
2021-02-19	47	7	27.0	-24.0	38	0	0.00	0.0	1
2021-02-20	60	25	42.5	-8.8	22	0	0.00	0.0	0
2021-02-21	68	34	51.0	-0.5	14	0	0.00	0.0	0
2021-02-22	69	28	48.5	-3.3	16	0	0.00	0.0	0
2021-02-23	78	33	55.5	3.5	9	0	0.00	0.0	0
2021-02-24	67	36	51.5	-0.8	13	0	0.00	0.0	0
2021-02-25	48	41	44.5	-8.0	20	0	0.00	0.0	0
2021-02-26	71	31	51.0	-1.8	14	0	0.00	0.0	0
2021-02-27	79	43	61.0	7.9	4	0	0.00	0.0	0
2021-02-28	63	46	54.5	1.1	10	0	0.00	0.0	0
Sum	1498	767	-	-	680	0	0.16	5.6	-
Average	53.5	27.4	40.4	-9.8	-	-	-	-	0.5
Normal	63.6	36.7	50.2	-	420	4	0.58	0.7	-

Midland International Temperature/Precipitation data for the Month of February 2021. The areas outlined covered the time frame of when the cold front first passed through the area until the cold air receded. The bolded numbers represent the warmest/coldest/wettest/snowiest days of the month. -9.8°F is the temperature departure from normal for the entire month, shattering the previous record by more than 1°F. Source: xmACIS Climate Data

There is more technical work on breaking down the setup for the historical cold that impacted the area. If you would like to hear more about this and dive into some more intricate details, feel free to contact us here at the National Weather Service in



Midland. Hopefully we don't see something like this for another 30 years!