The February 2021 Cold Wave

Unprecedented…Or Not?

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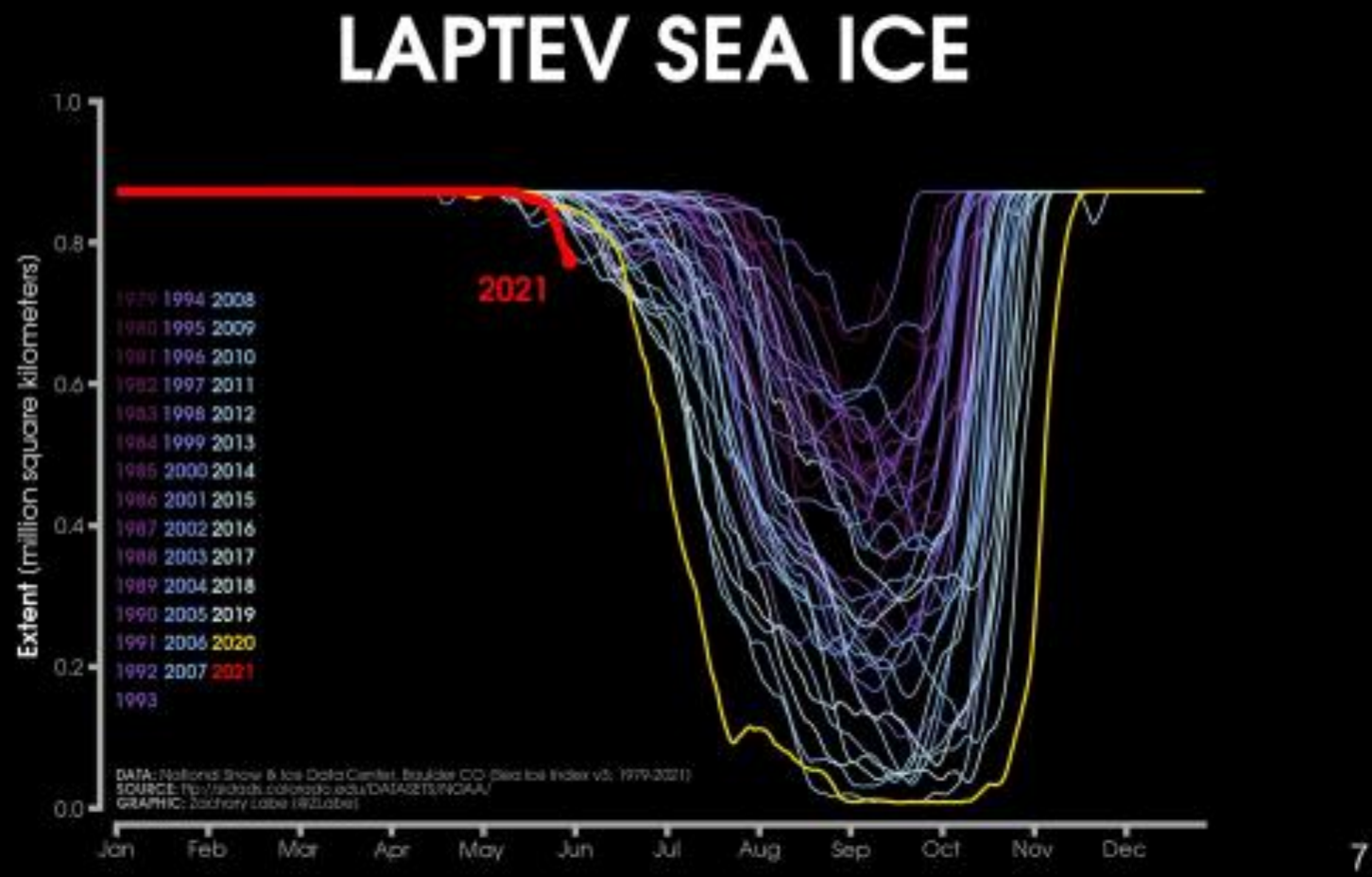
ESIG Meteorology & Market Design for Grid Services Workshop
Plenary Session | June 4, 2021

Rapidly declining sea ice extent in summer and early autumn demonstrates climate change in the Arctic

(Laptev Sea is in the Siberian Arctic)



(Data as of 2 June 2021)

University of Colorado Boulder

7

This keeps me up at night. Climate change is an existential danger.

Feb 14 in NE Portland © Justin Sharp, 2021

February Cold Wave

Driven by five mid-latitude storms but often discussed synonymously as Winter Storm Uri

Feb 18 NYC
© Justin Lan/EPA cia Shutterstock

Uri: A major coast-to-coast storm that spread snowfall and damaging ice from the Northwest into the South, Midwest and Northeast Feb 12-16, 2021. The storm was followed by the coldest temperatures in decades in the south-central states

The Weather Channel

(https://weather.com/safety/winter/news/2021-02-14-winter-storm-uri-south-midwest-northeast-snow-ice)

Feb 15: Post Uri Houston Freeway

Outline: What happened? What caused it? How unusual was it?

The National Impact (Uri and Viola)

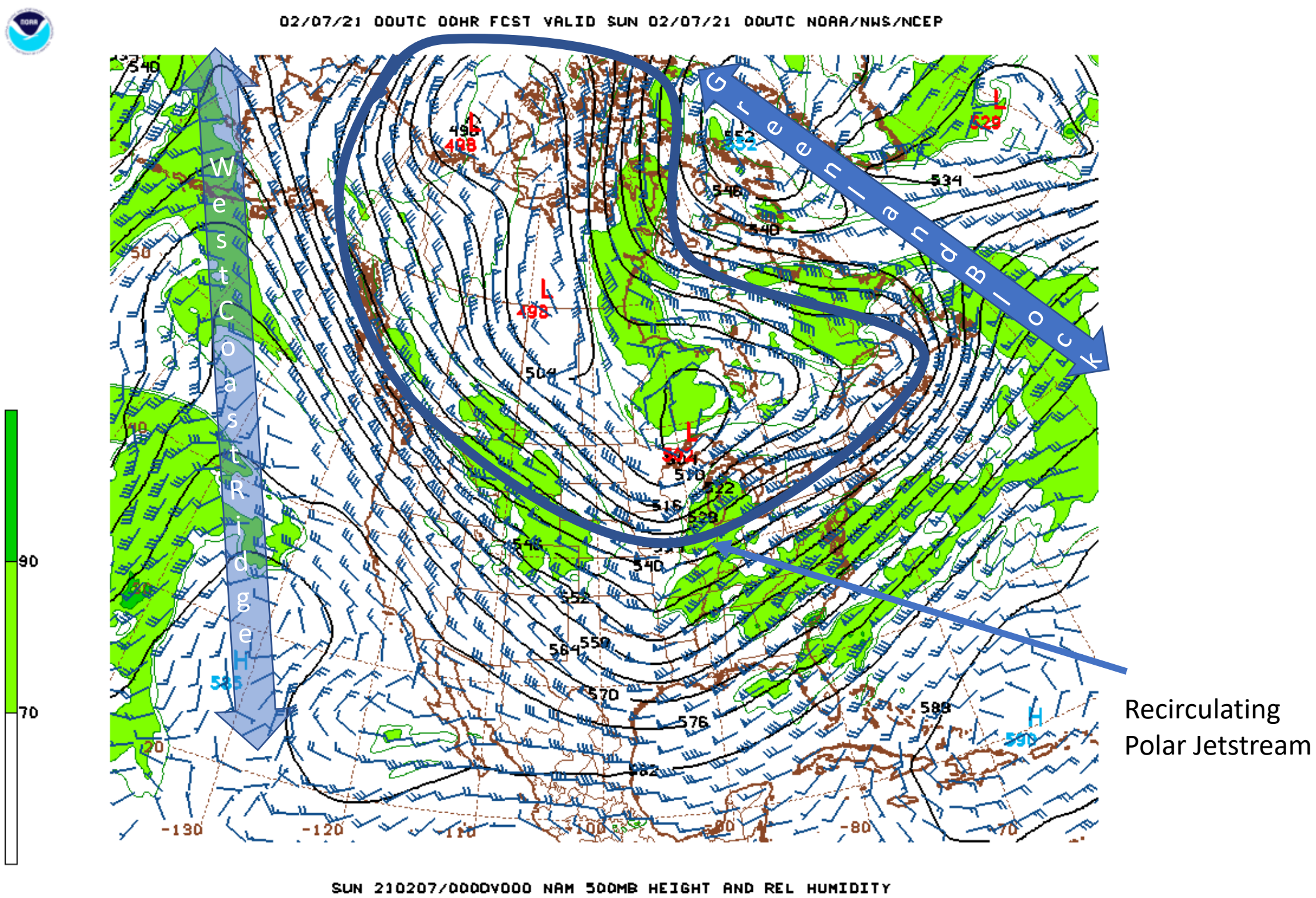

Iced fence and roses
Feb 15, Portland, OR
© Justin Sharp

Galveston Beach, TX.
Note the sea-smoke
Over the Gulf

- Heavy snow and ice in the Pacific Northwest
  - 11” of snow in Seattle, 5-11” in Portland
  - Massive ice accumulation in Oregon…the most I’ve ever seen
  - Worst utility Oregon outages in history. Over 730,000 without power, some for many days. 200,000 in Portland alone
- Blizzard conditions in Albuquerque, NM
- Heavy snow across central and southern plains
- Snow, sleet and ice to the Texas Gulf Coast
  - 80% of Texas was snow covered
- On February 16, 73% of the area of the Lower 48 states was covered by snow, the most widespread snow cover in the contiguous U.S. in at least 17 years
- Behind Uri, temperatures plummet to the Gulf Coast
- Common mode failures combine with extreme demand to take ERCOT within minutes of grid collapse. Power cut to over 4.5 MILLION households.

Why The Very Active Weather in January and February?

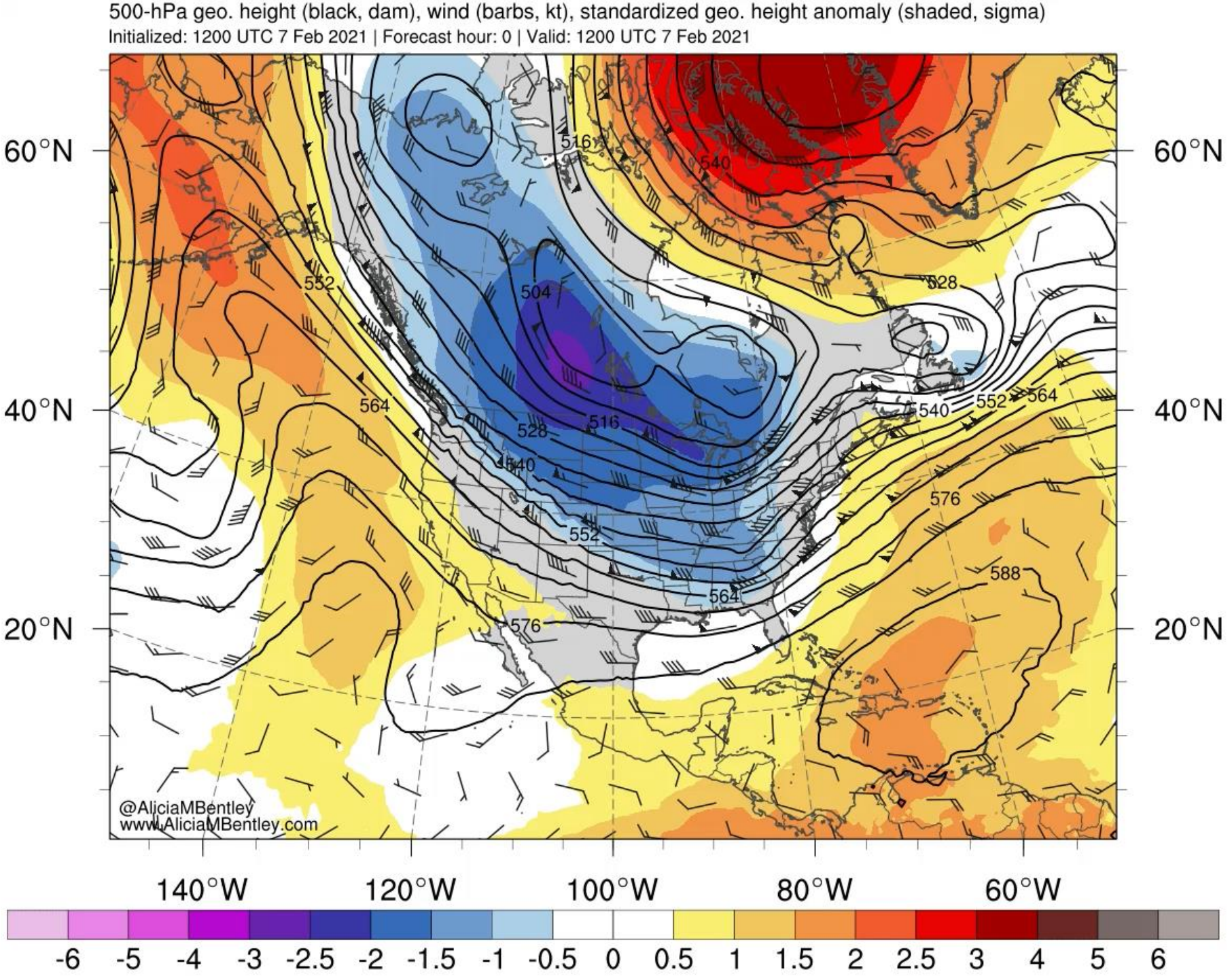
- A Sudden Stratospheric Warming (SSW) Event occurred on January 5, 2021
  - Such events occur in winter about once every 2 years
  - The stratospheric polar vortex weakened in late December, and mean winds reversed in January followed by rapid stratospheric warming
  - These events disrupt the polar jetstream and favor its amplification for several weeks
  - This often opens the door to cold air outbreaks…and to warm air moving north
  - Where the cold air ultimately invades depends on global weather patterns
- The Greenland Block was moderately strong throughout early February
- A blocking west coast ridge developed
- These features force Arctic air down through Canada into the US



Recirculating
Polar Jetstream

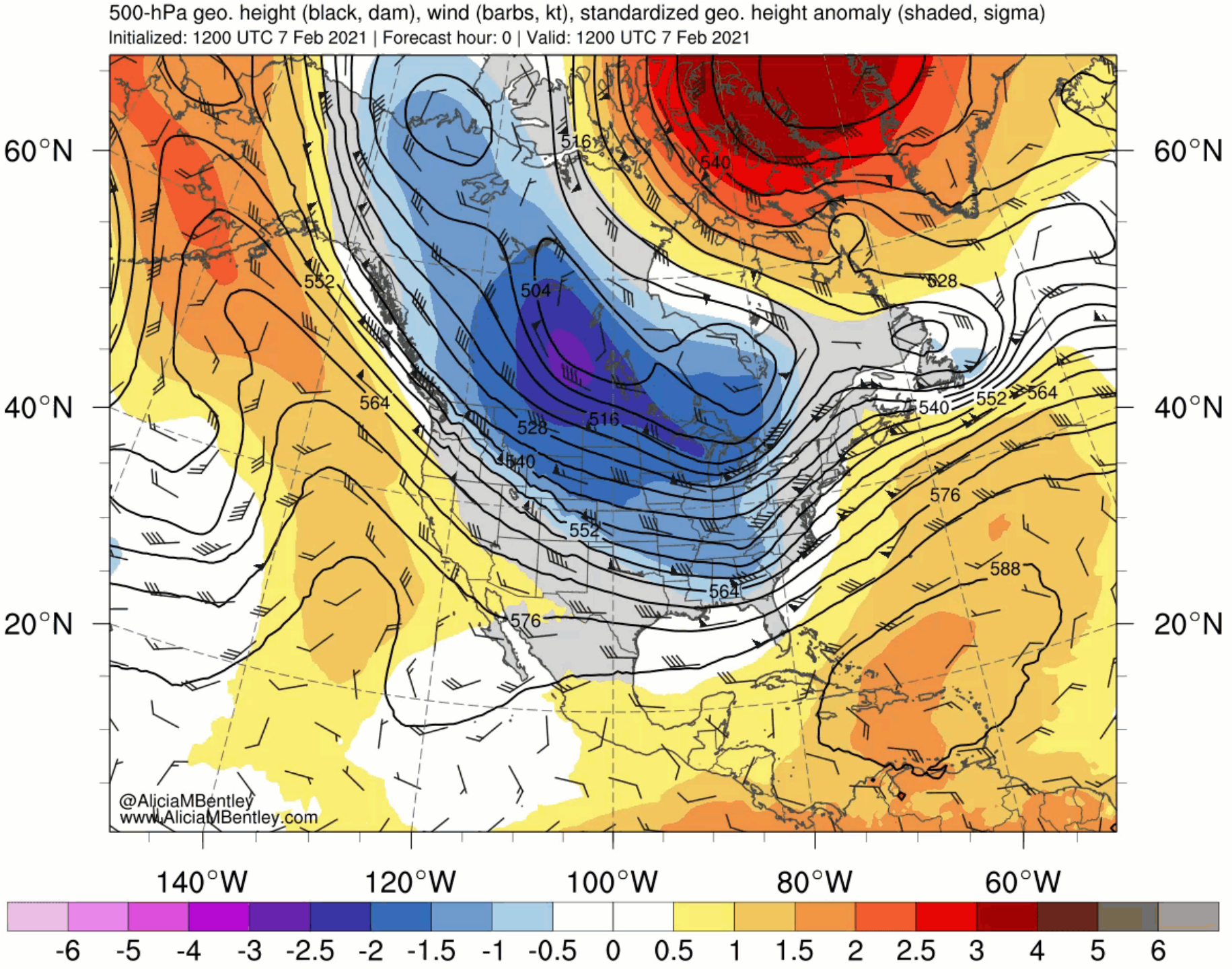
Upper- level flow evolution

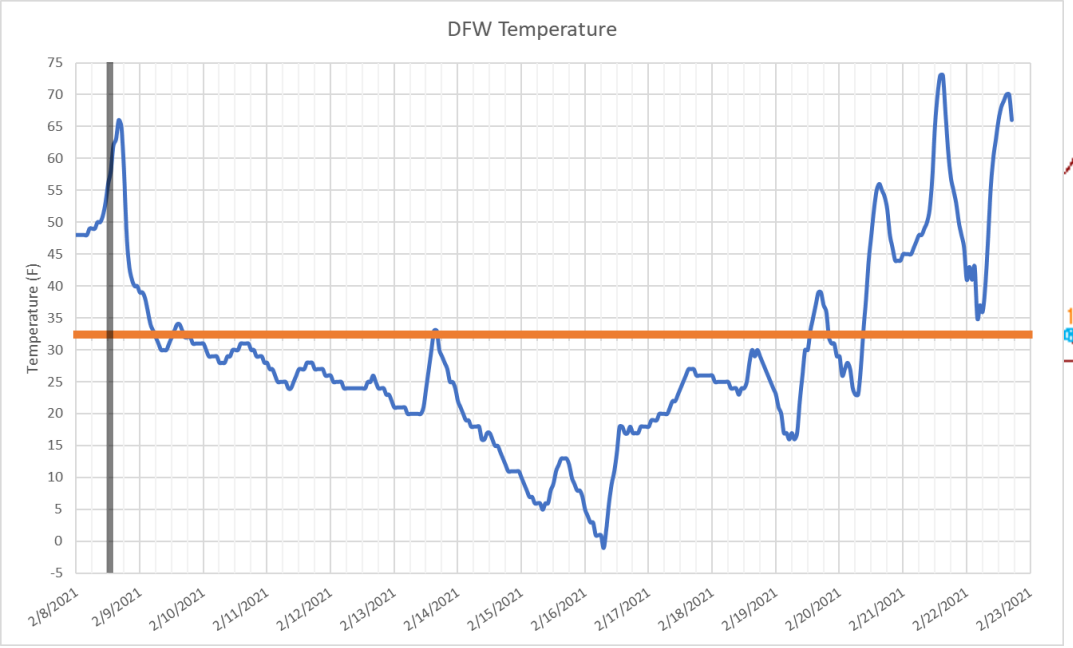
Watch the ridge, trough, ridge triplet. Without getting into details, the flow is blocked, preventing the weather pattern from progressing and leading to constant reinforcement of cold air from the north.



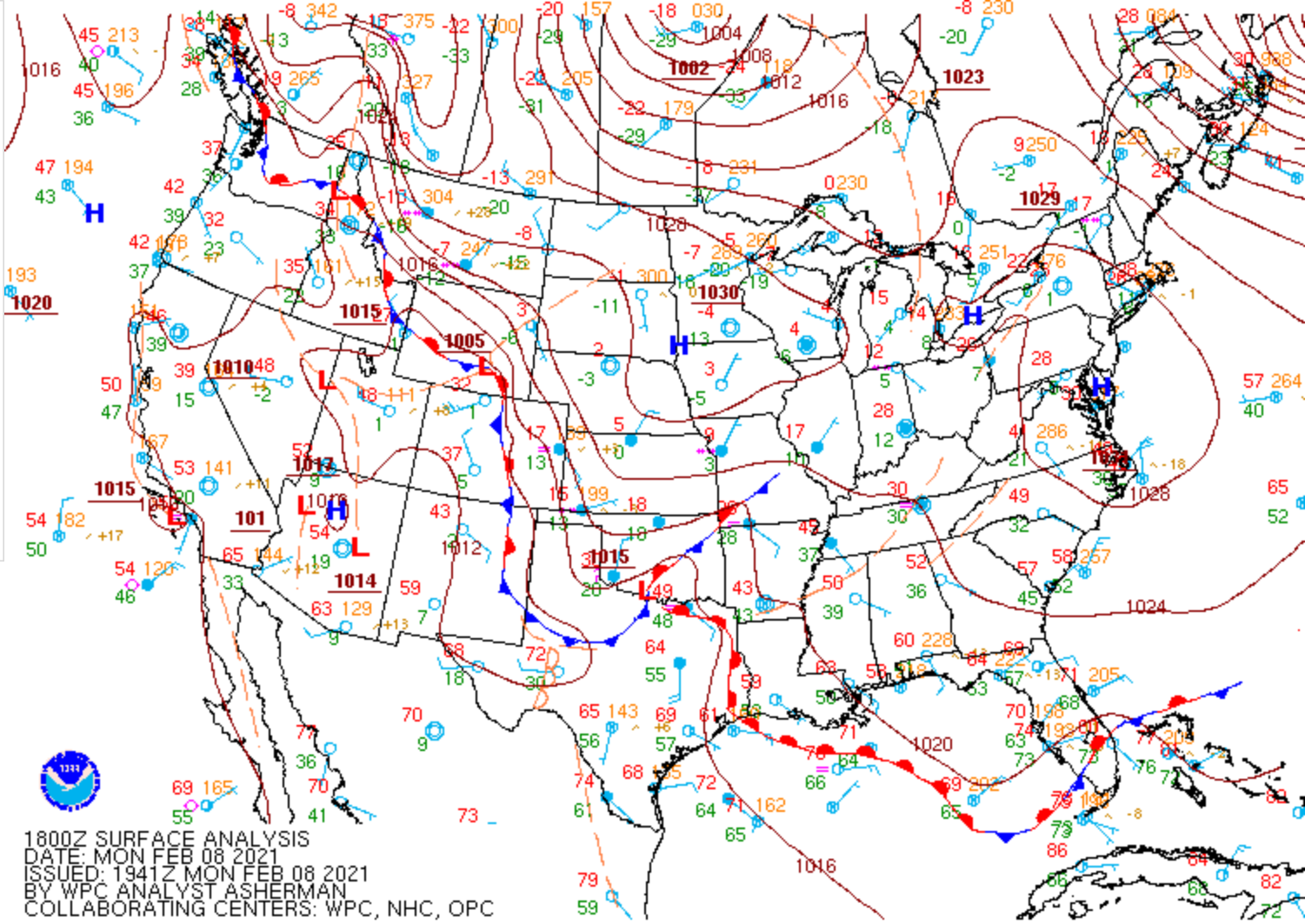
Upper- level flow evolution

Watch the ridge, trough, ridge triplet. Without getting into details, the flow is mostly blocked, preventing the weather pattern from progressing and leading to constant reinforcement of cold air from the north.

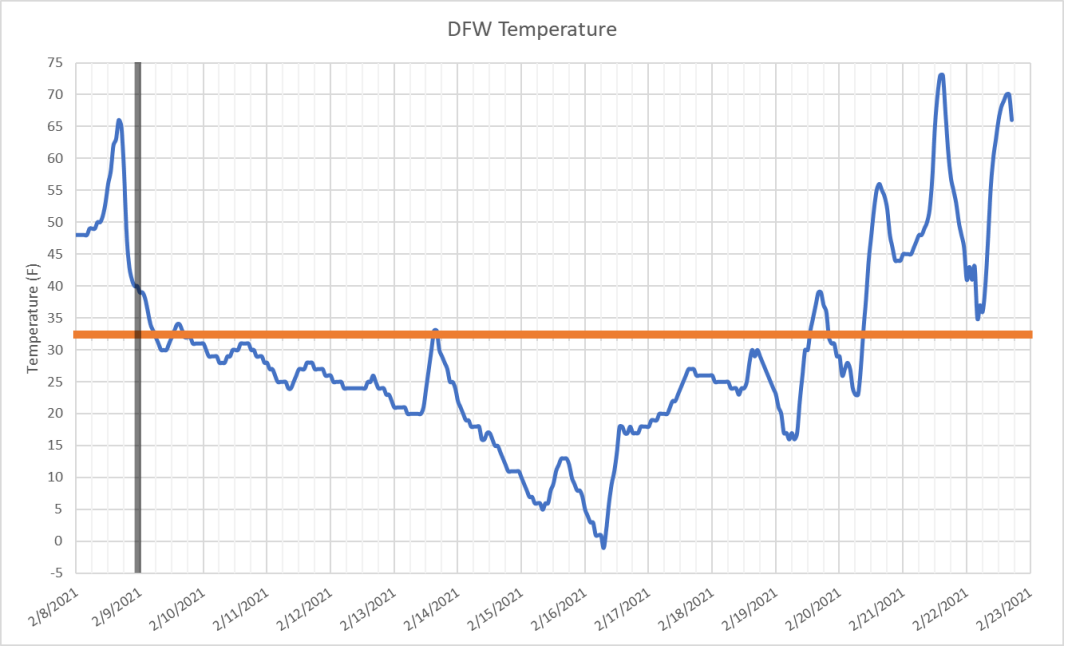




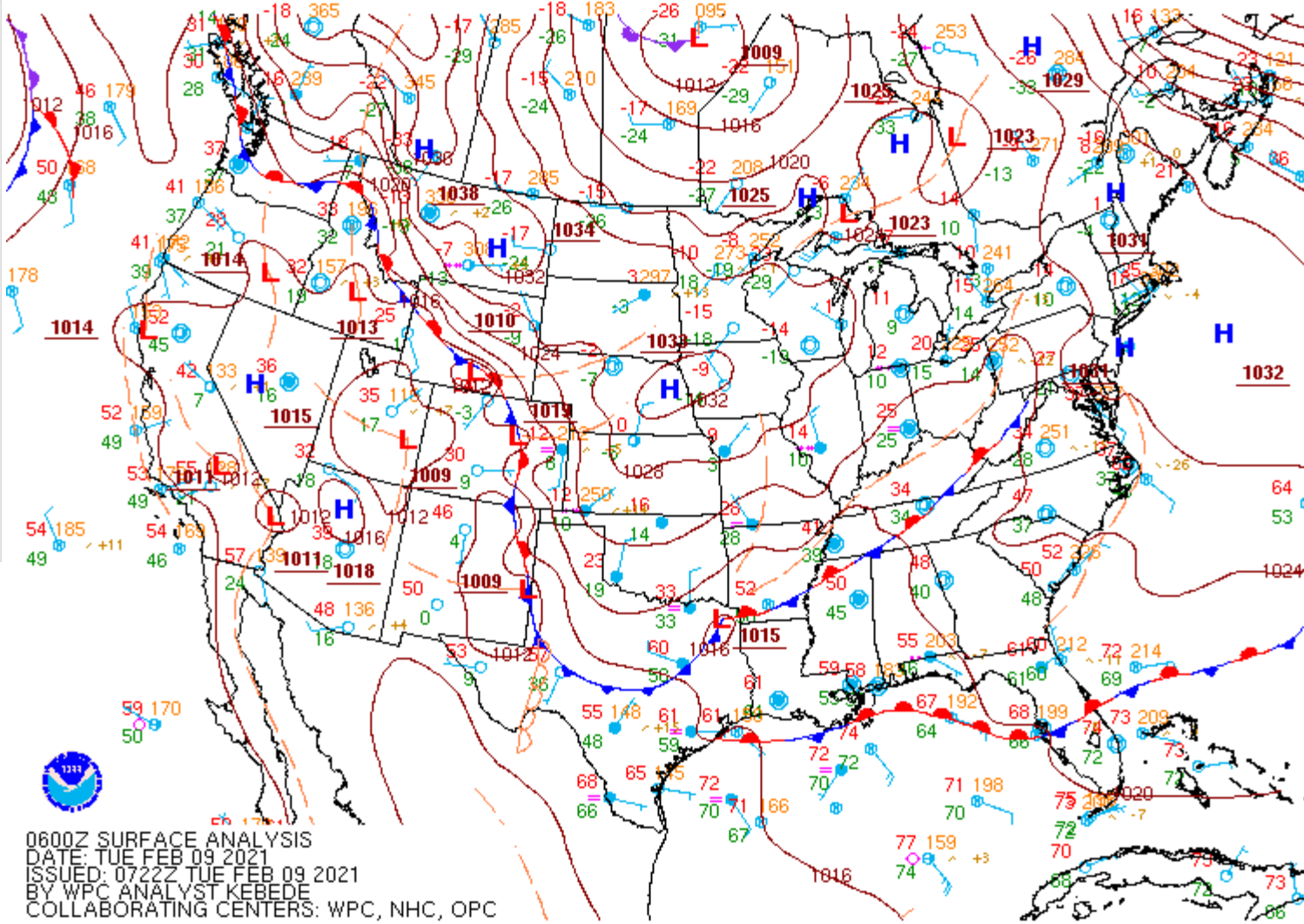
- Roland passes through Texas
- Cold air pushing into Texas
- DFW temperature about to drop
- Note the reasonable wind resource
- Stationary front along Rockies.



20210208 12 CST Surface Map



- Cold air continues south
- Roland isn't well defined but creates swath of frozen precip as it moves NE
- Heavy snow in Ohio Valley.



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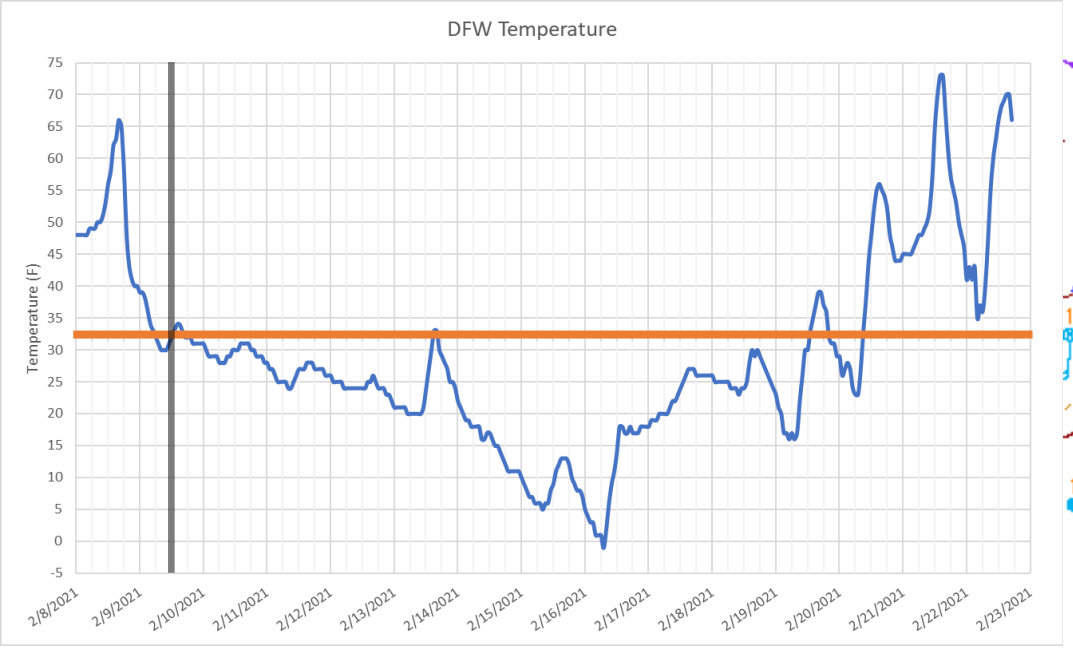
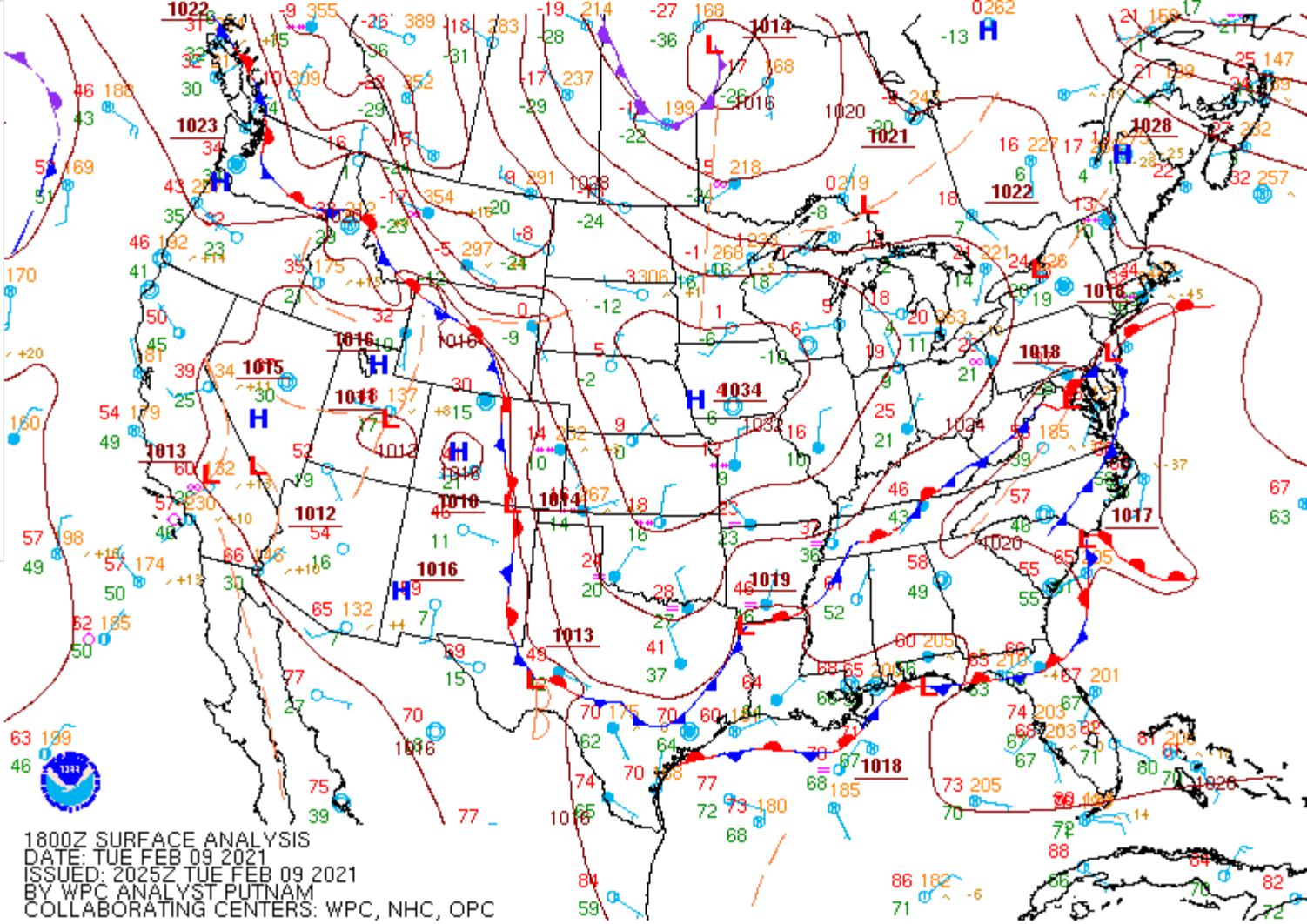
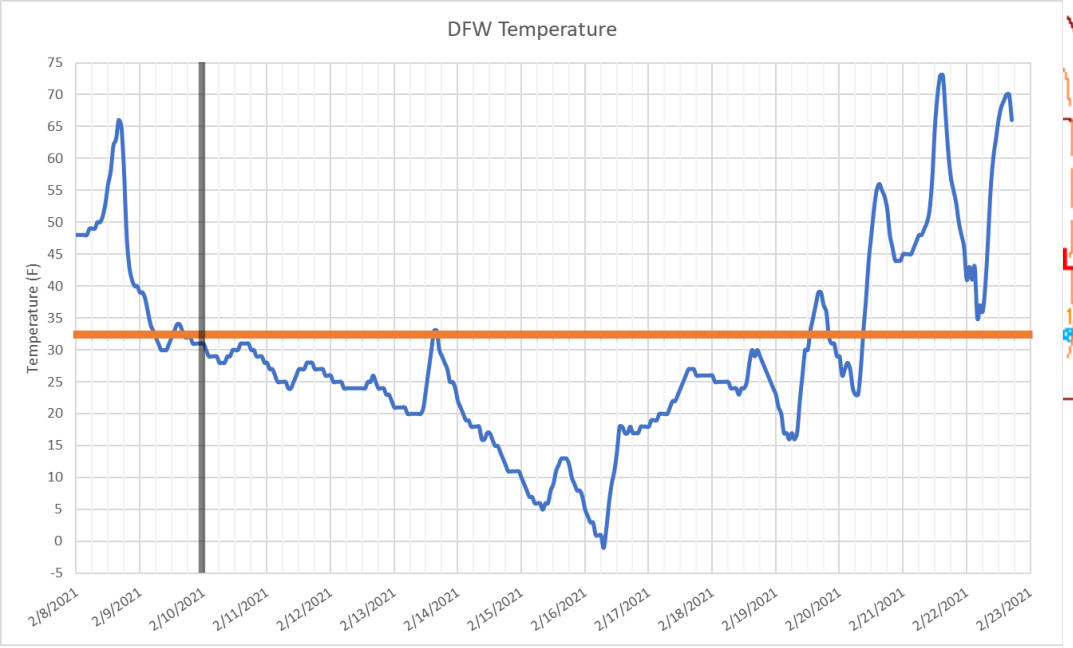


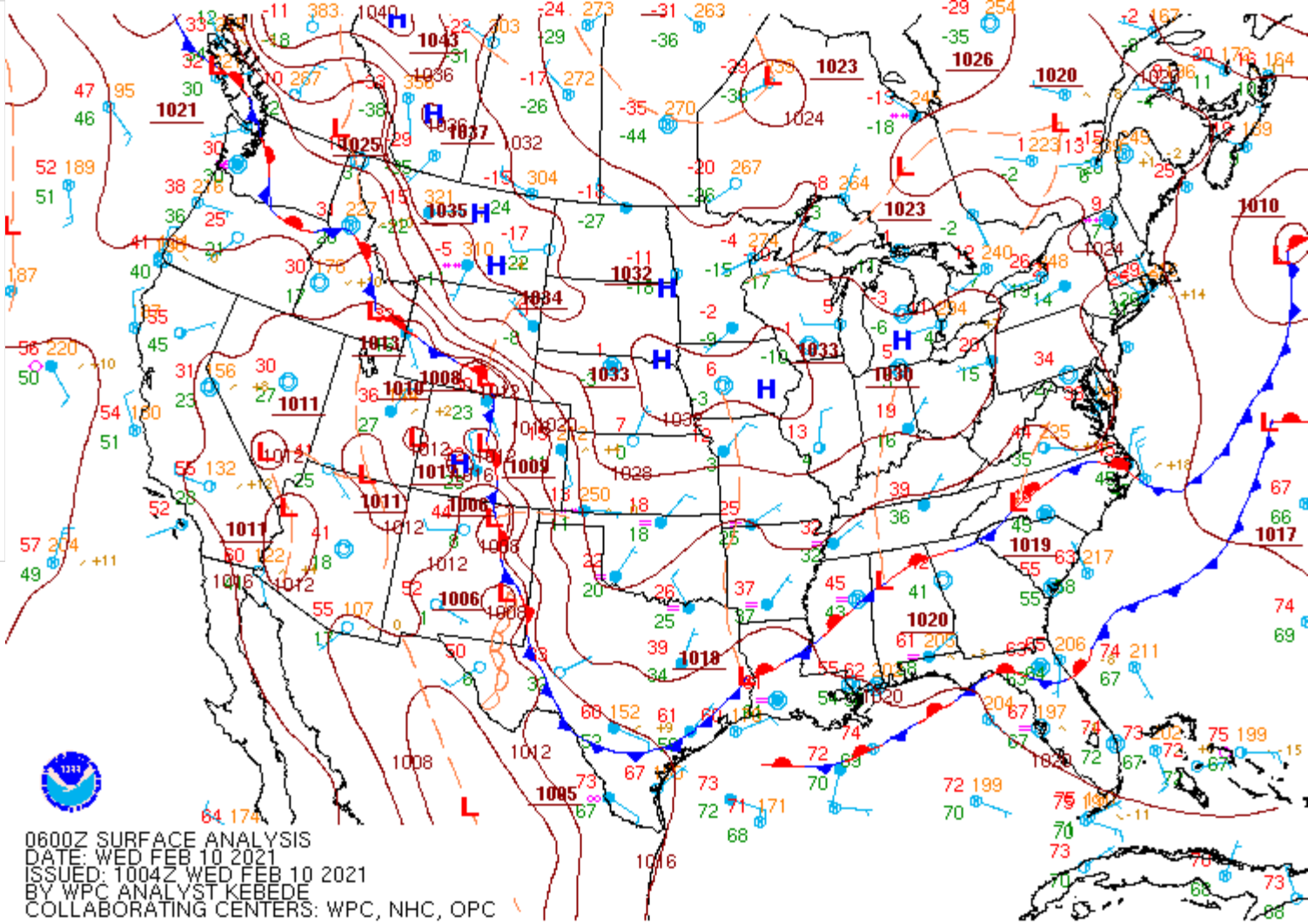
- Roland exits off coastal NJ
- Cold air continues to filter slowly south in Texas
- Midwest surface high builds



20210209 12 CST Surface Map



- Cold air advection roughly offsetting daytime warming
- Fronts largely stalled
- Weak waves keep precip going
  - TWC calls this Shirley but not well-defined



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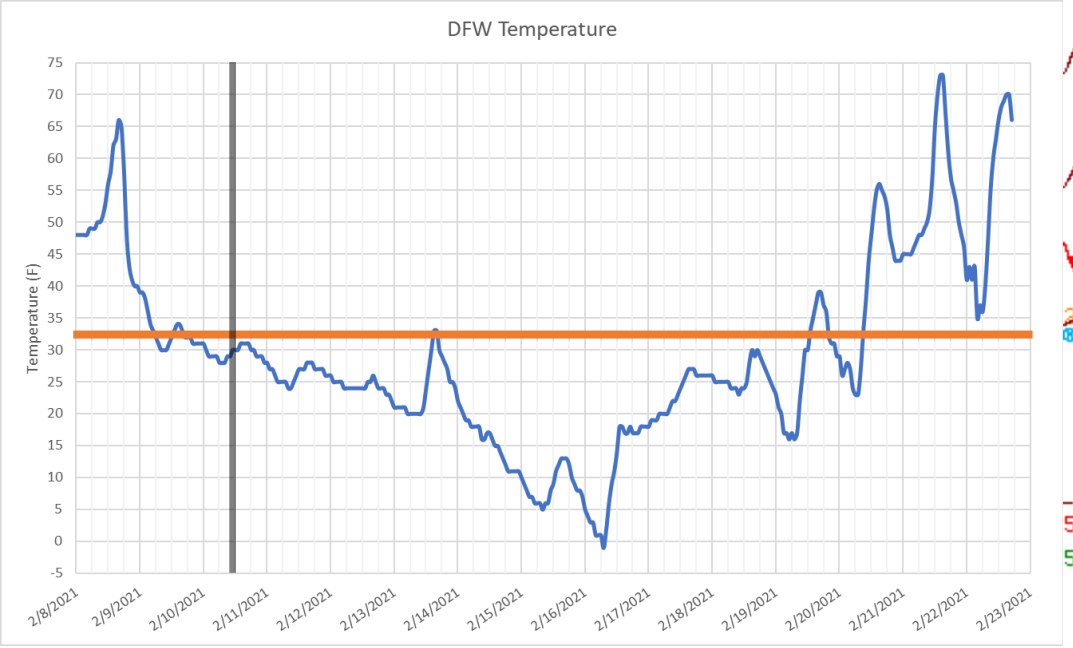
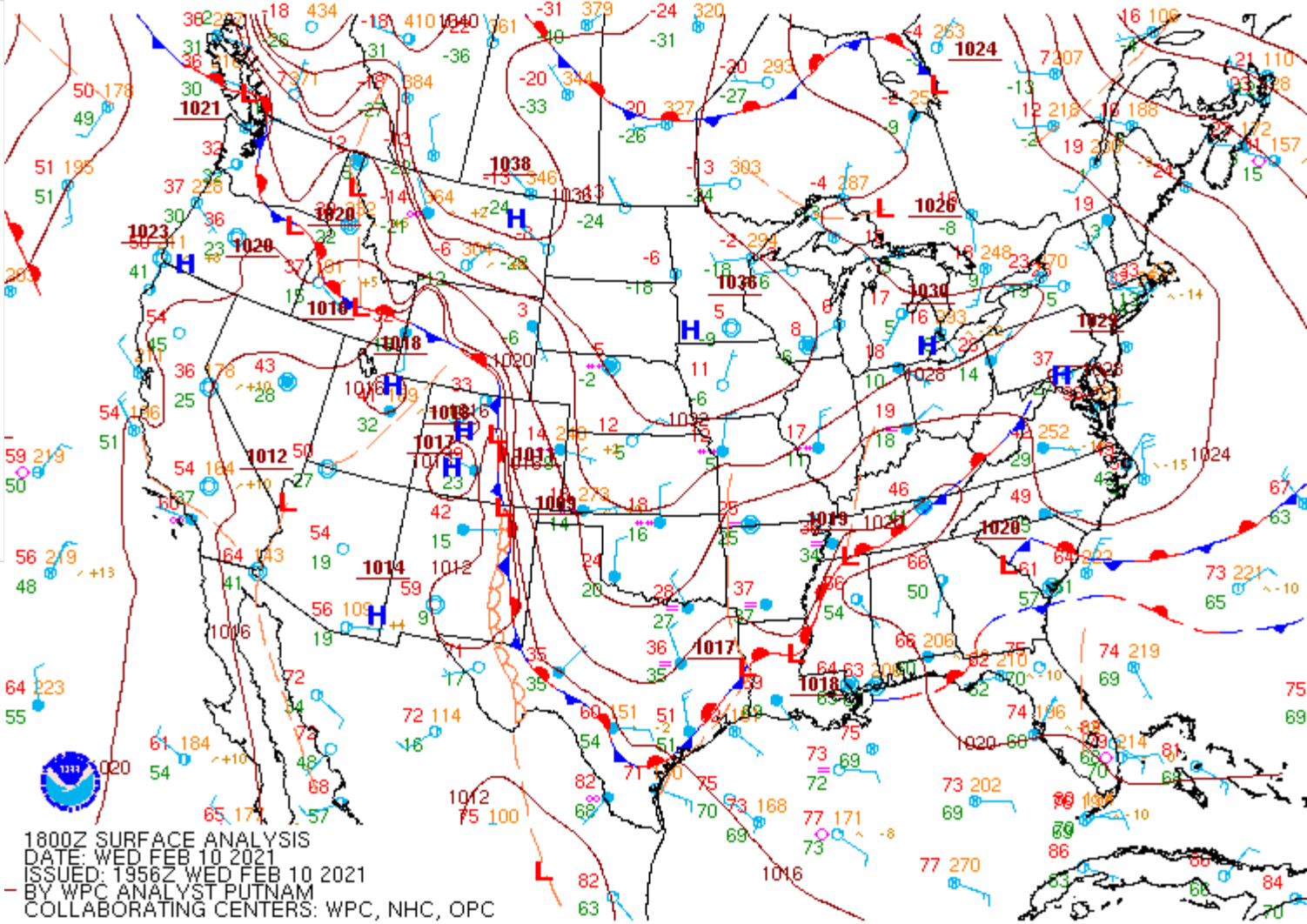


- Weak northerly flow continues
- Cold air slowly moving south and deepening
- Little synoptic forcing for Shirley



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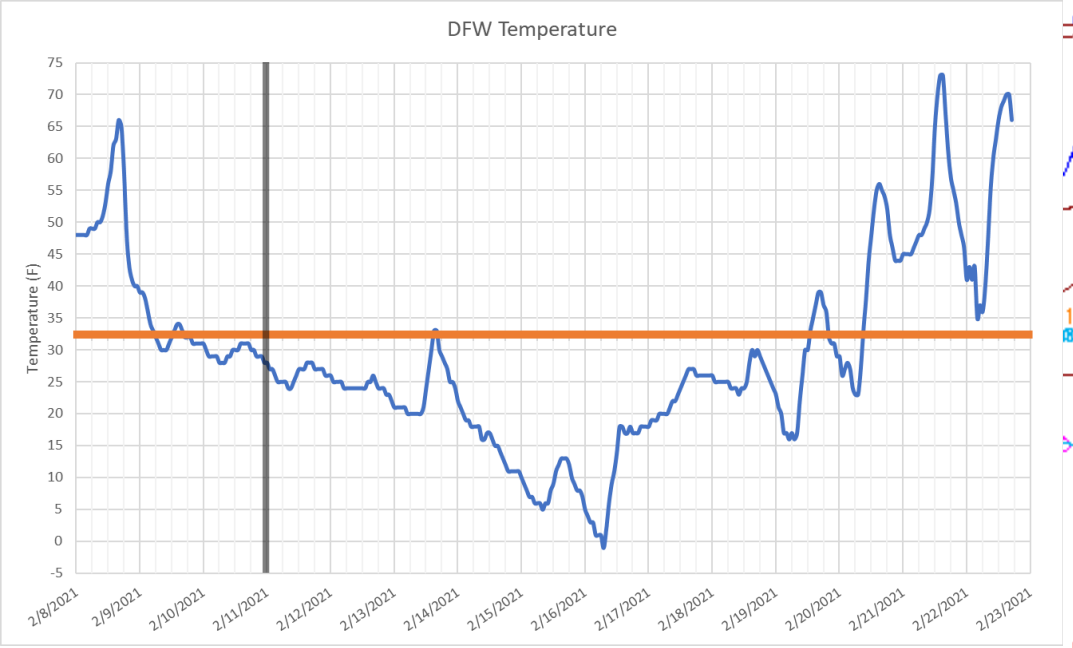
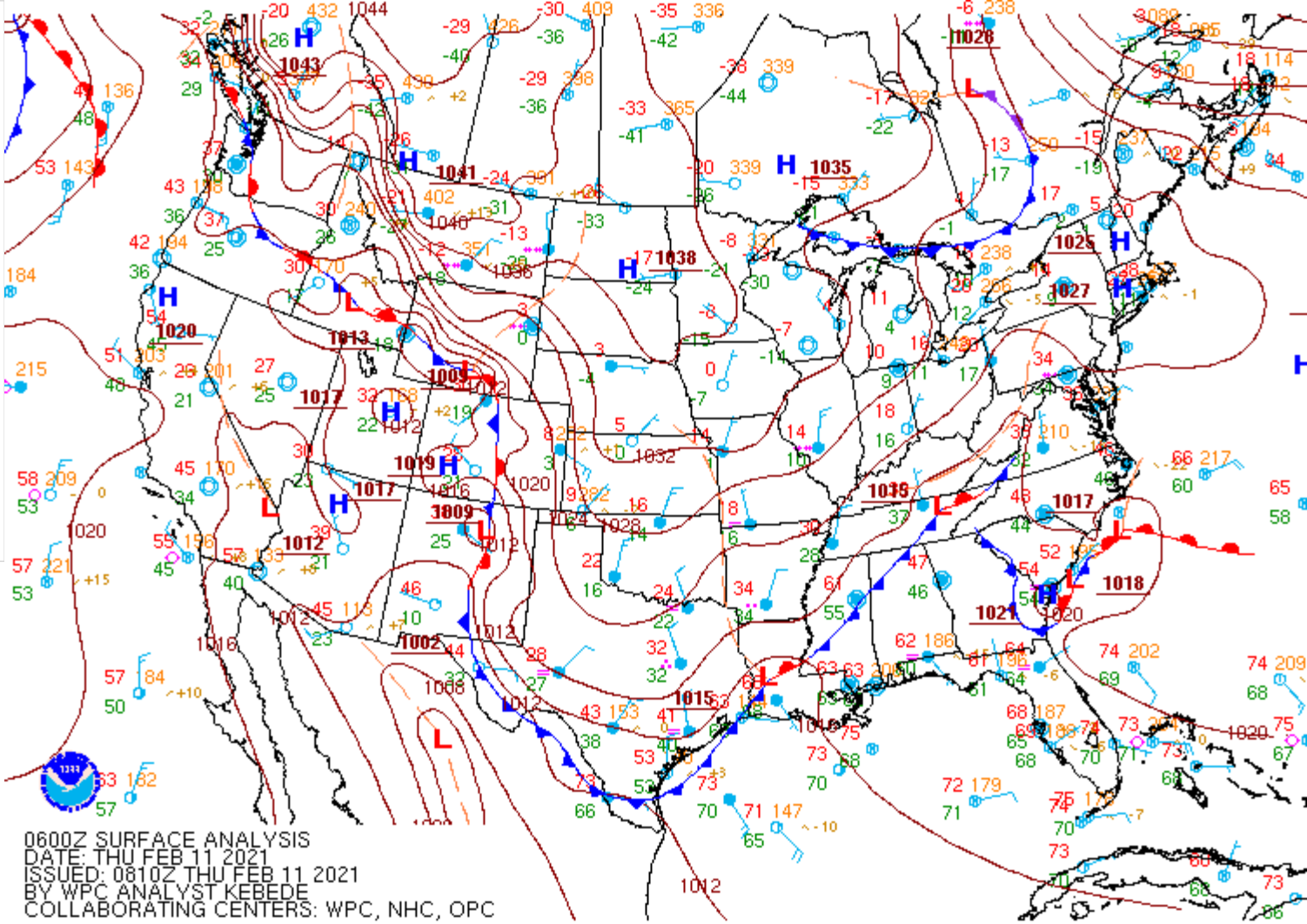


- Shirley exits mid-Atlantic coast
- Cold continues to sag south to Texas Gulf coast with slightly enhanced northerly gradient
- Tabitha approaches PNW bringing snow and ice



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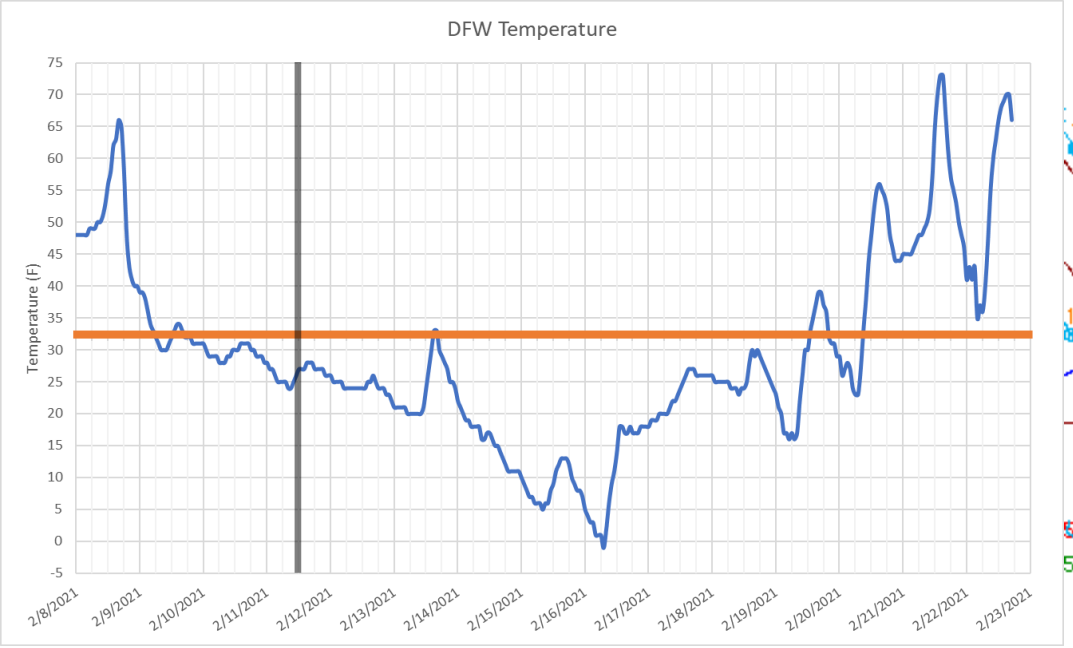
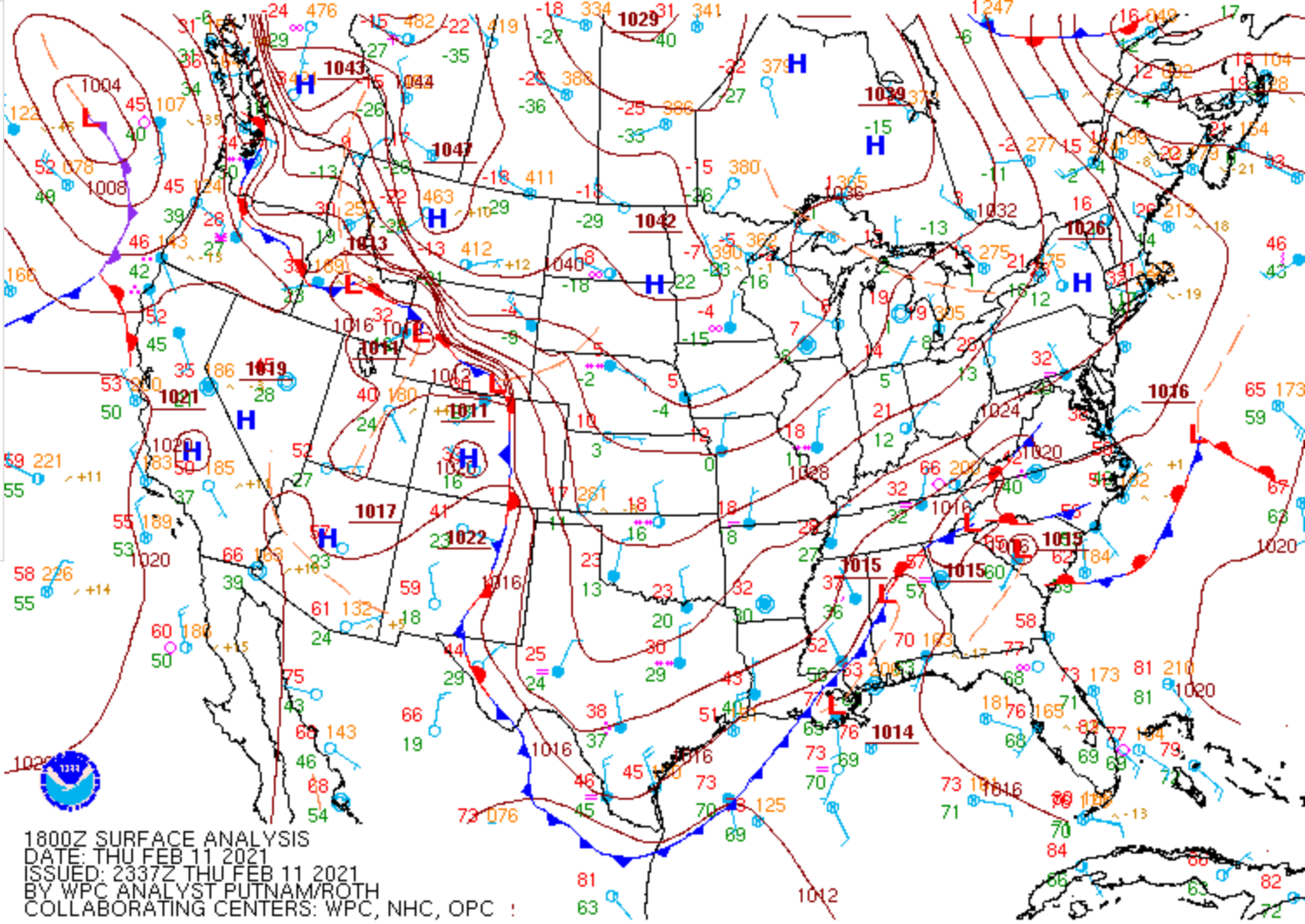
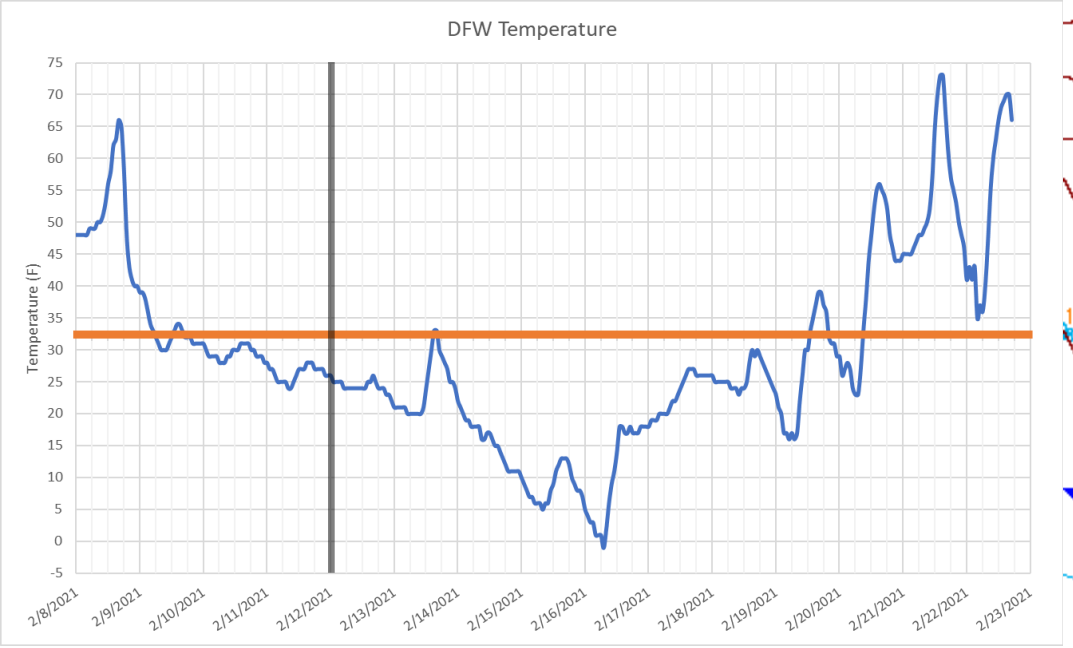


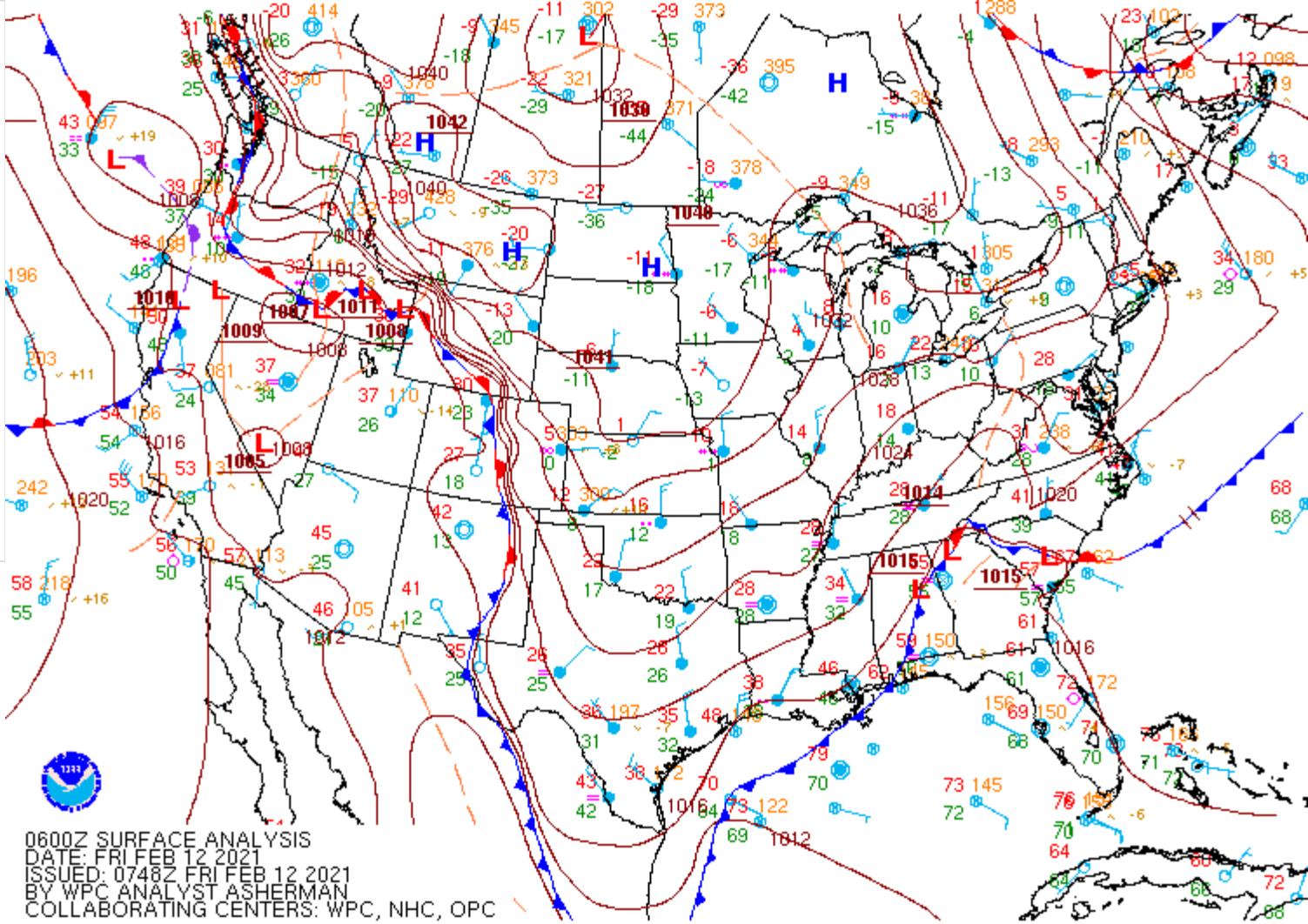
- Reinforcing push of cold air
  - Note strengthening wind resource associated with it
  - Tabitha brings moderate snow to PNW



20210211 12 CST Surface Map



- Cold air continues to march south across Texas and deep south driven by strengthening surface high pressure
  - Again, note the correlation of decreasing temperature and wind resource
  - But also note that resource is weak further north where extreme cold is entrenched



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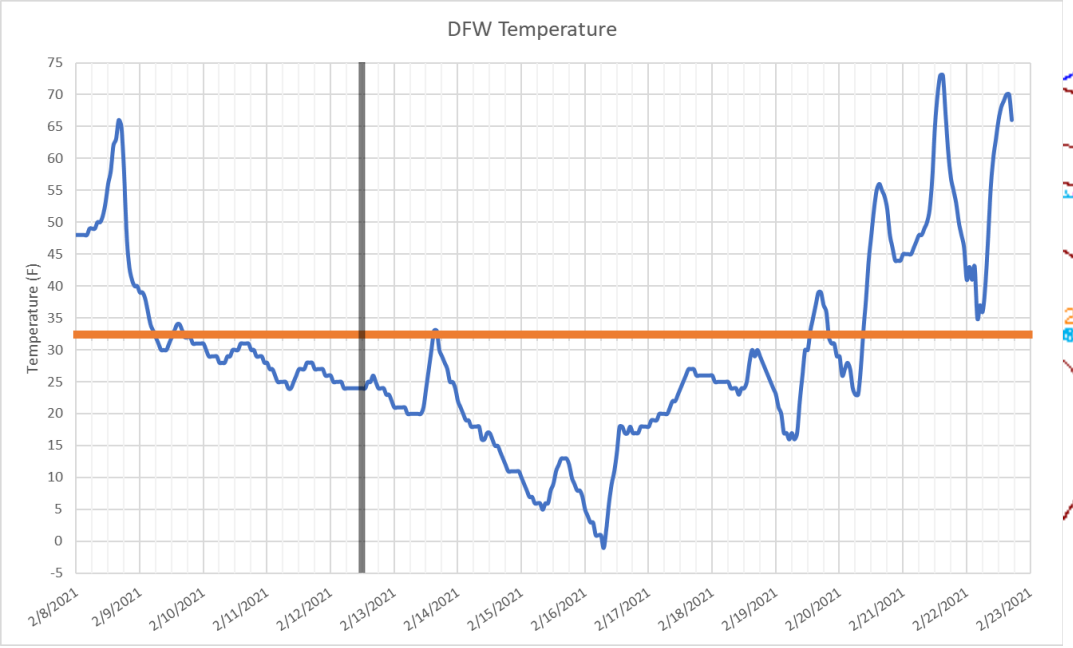
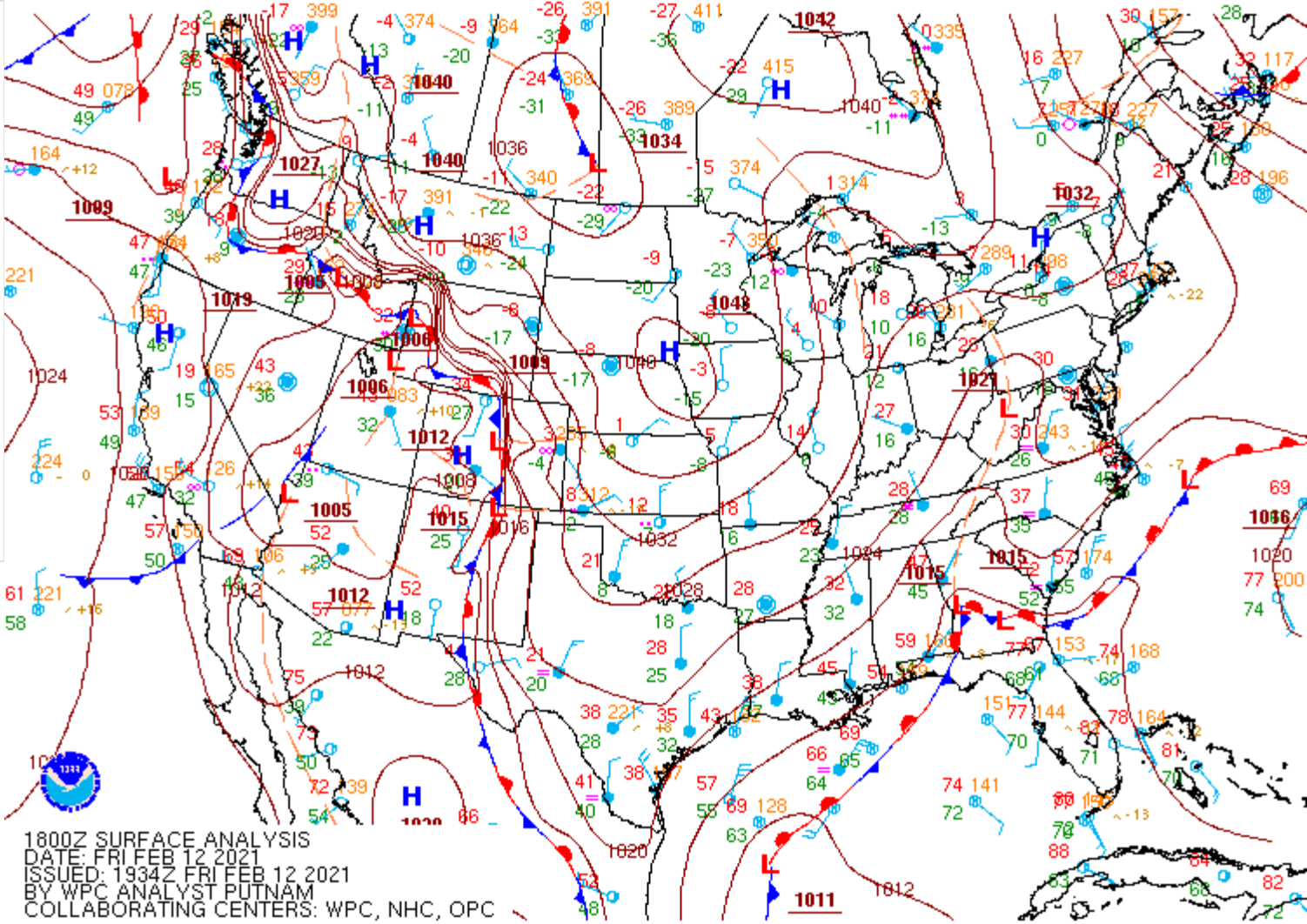
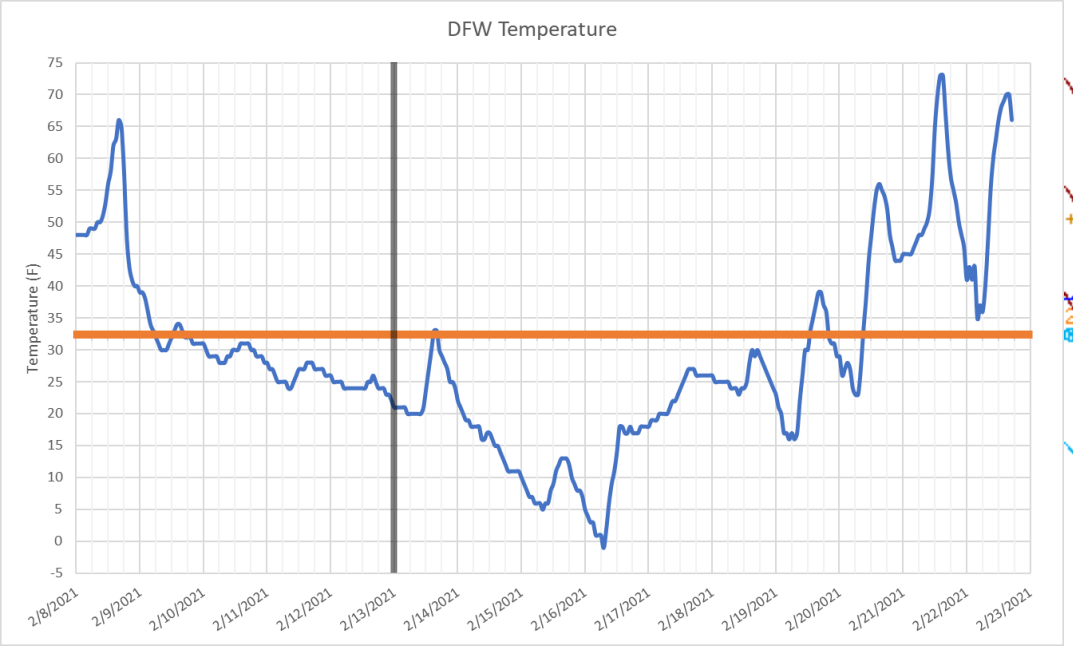


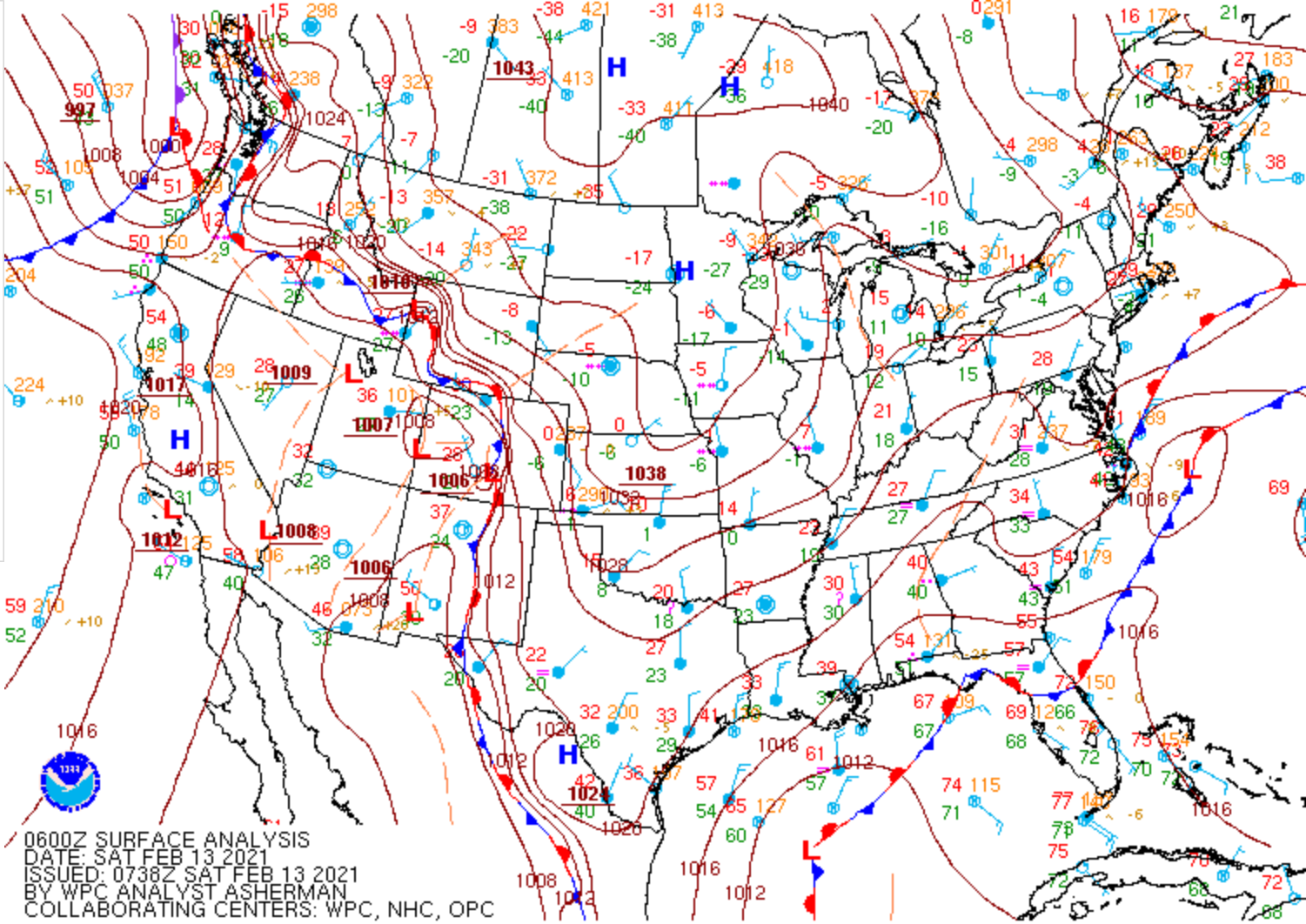
- What TWC calls Tabitha is now moving across southern plains bringing snow and ice
- But these storms aren't coherent like a tropical cyclone. Not fond of TWC naming methodology
- Gradient picks up bringing more cold air further south.



20210212 12 CST Surface Map



- Weak disturbances on the front over the Gulf continue to circulate moisture over shallow cold air leading to more freezing rain across wide area
- Cold continues slowly south
- The feature here is the lack of major action…just continual slow reinforcement.



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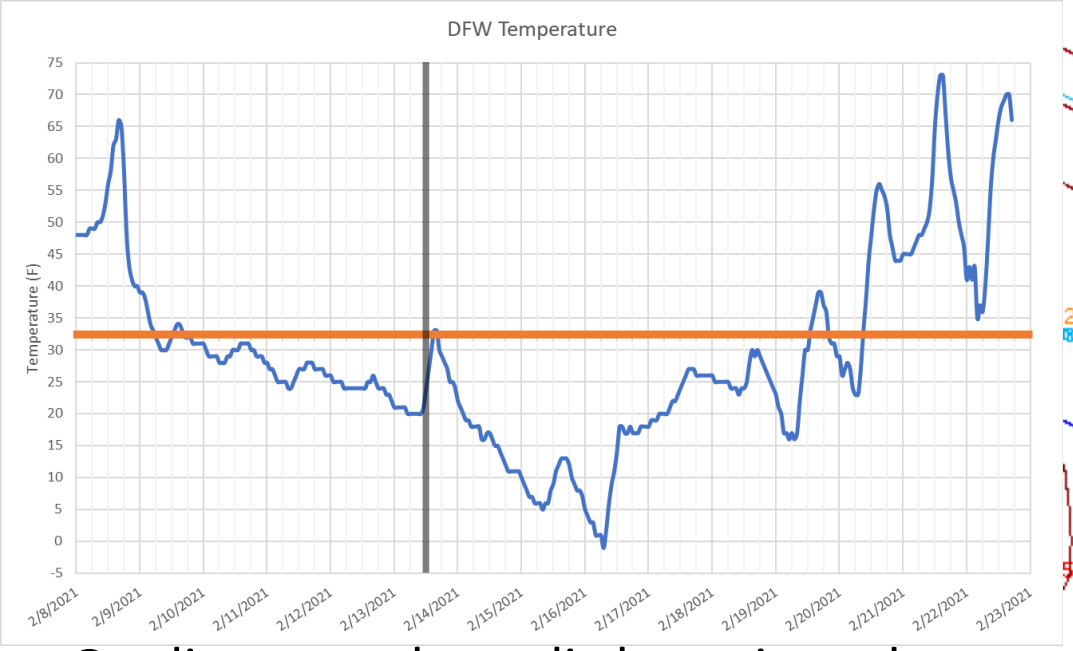
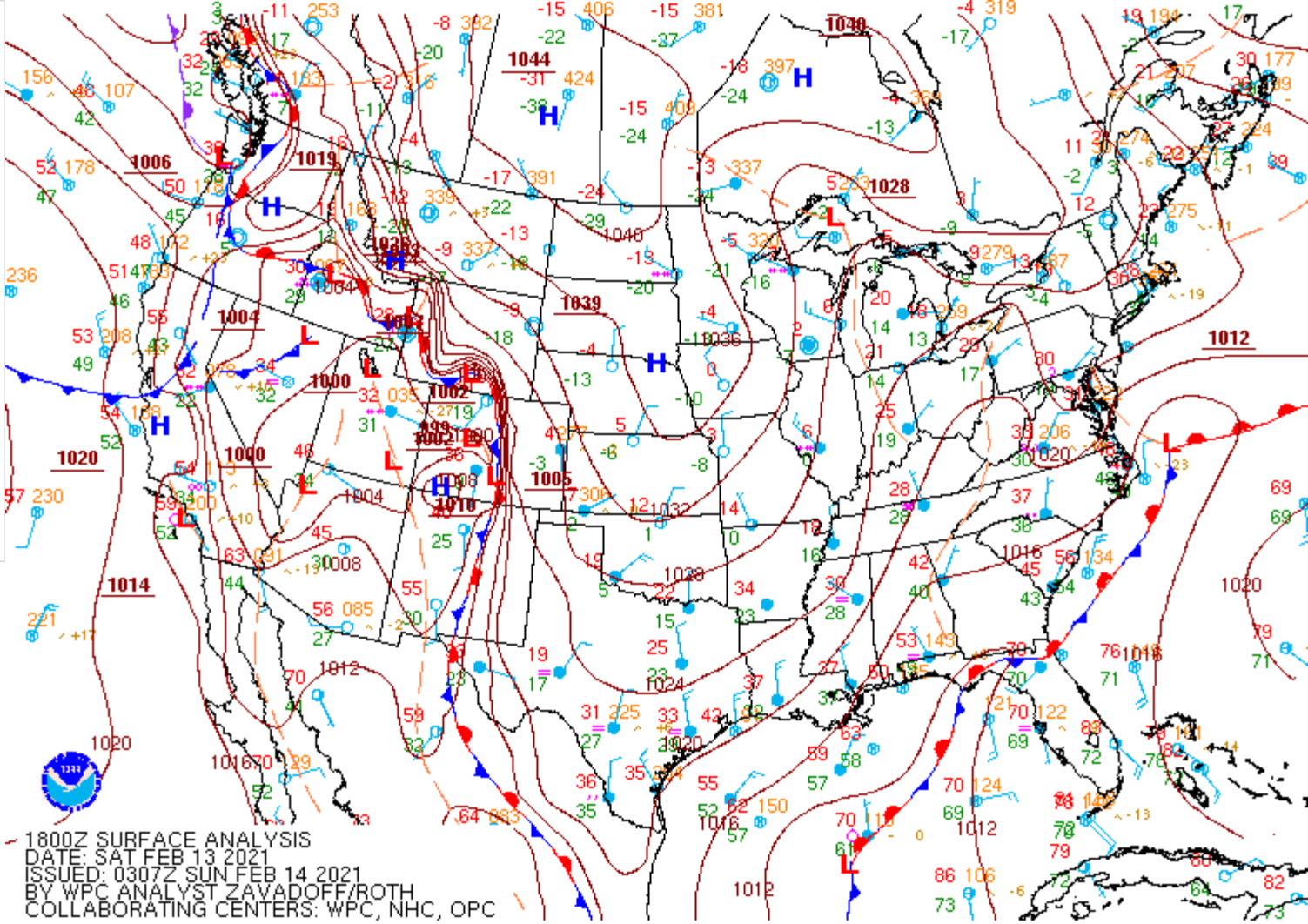


- Gradients weaken a little again and daytime heating briefly overwhelms cold air advection in some of Texas and deep south
- Continued weak activity on mostly stalled frontal boundaries
- Note light fog in Texas that has been a feature for several days…cold air over moist ground/water
- Uri moves inland in PNW bring widespread freezing rain



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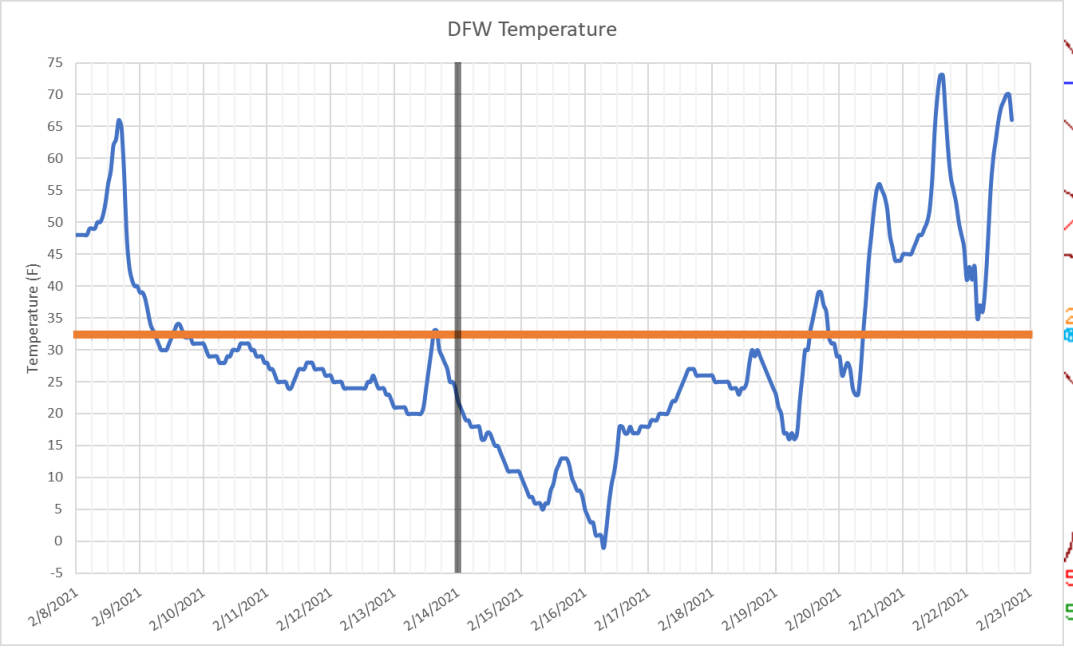
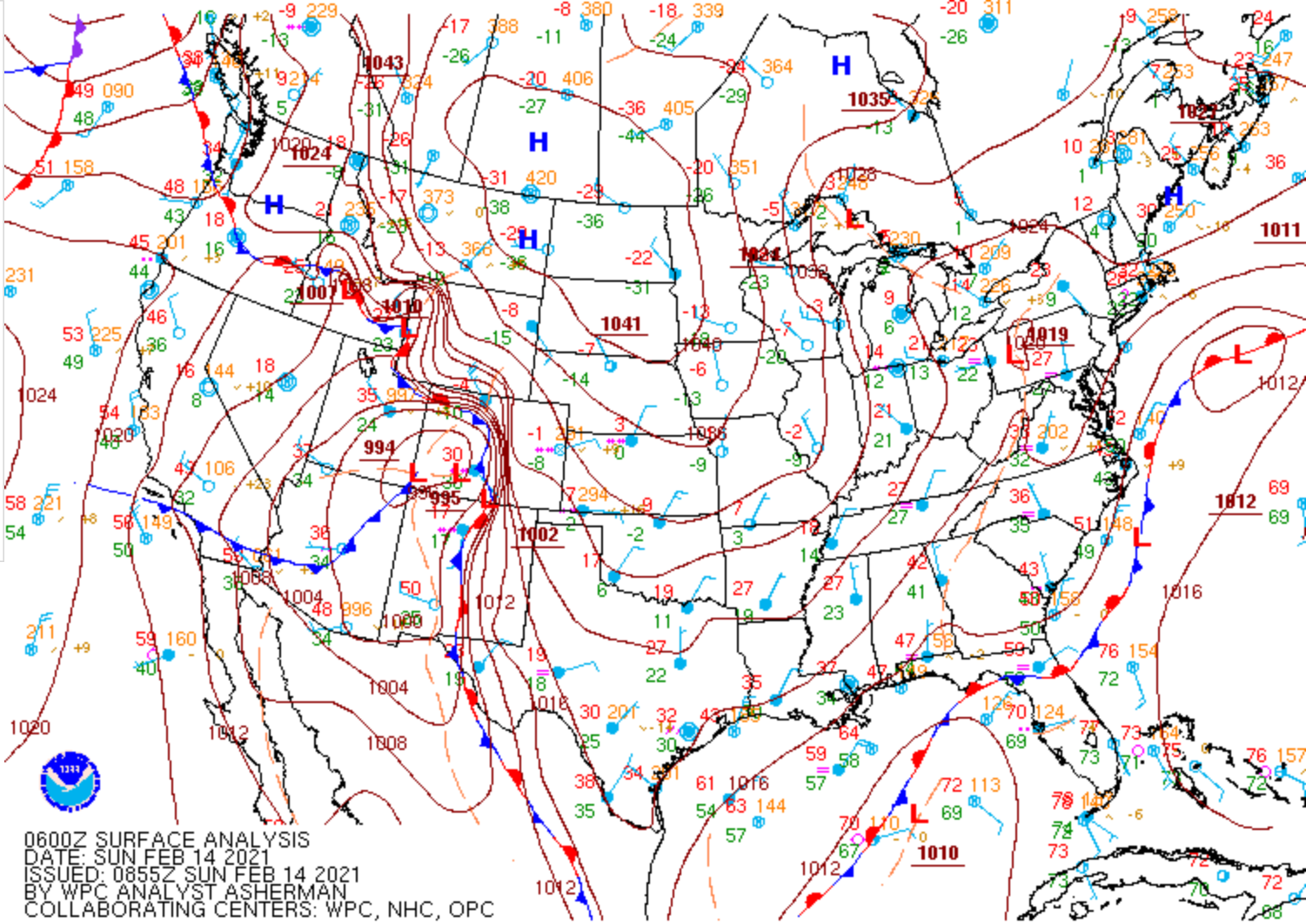
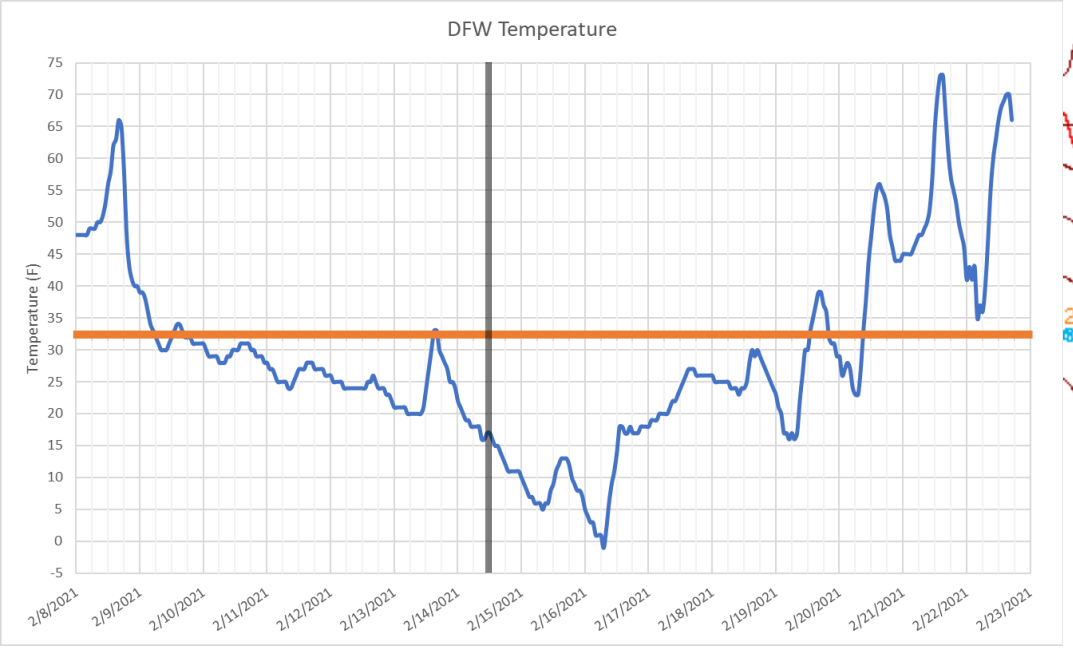


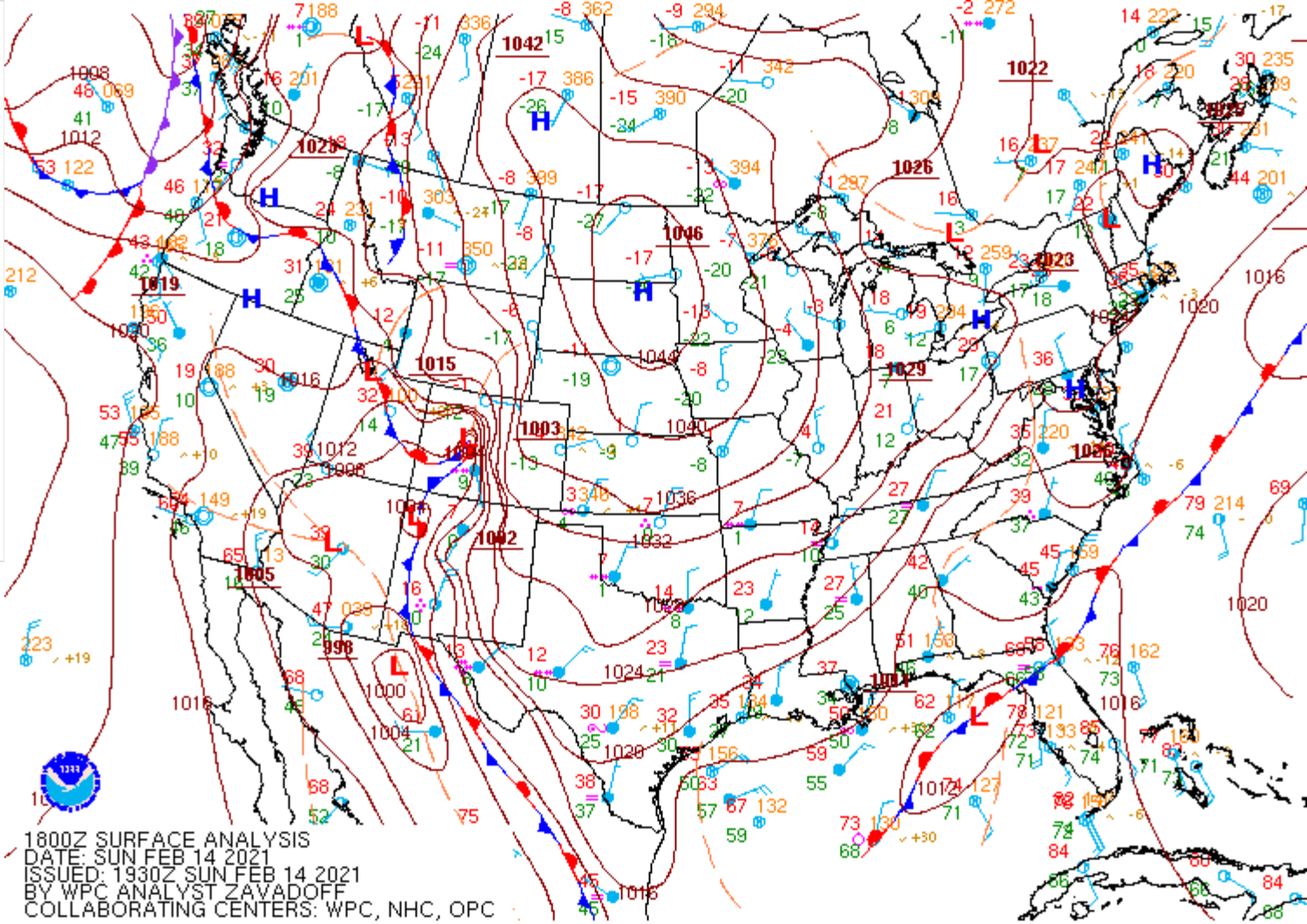
- Uri impacts Four Corners region and begins to pull more cold air southwest
- Cold remains thoroughly entrenched



20210214 00 CST Surface Map



- Cold air is reinforced as the passage of Uri and high pressure building over Dakota's strengthens gradients
- Significant winter precipitation across much of south US coastal areas.



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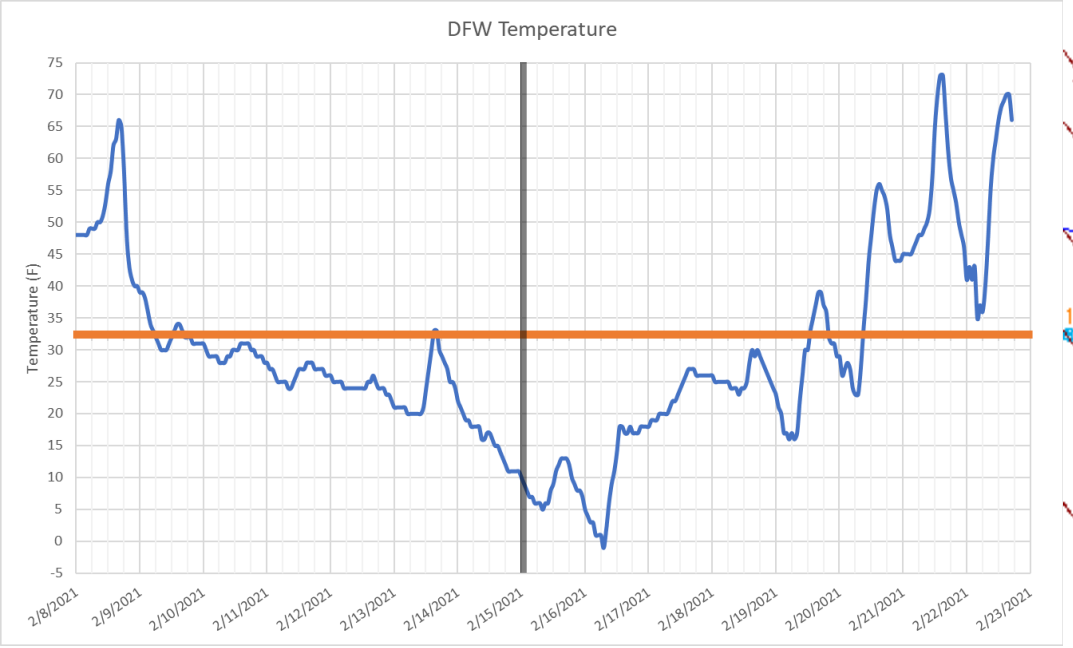
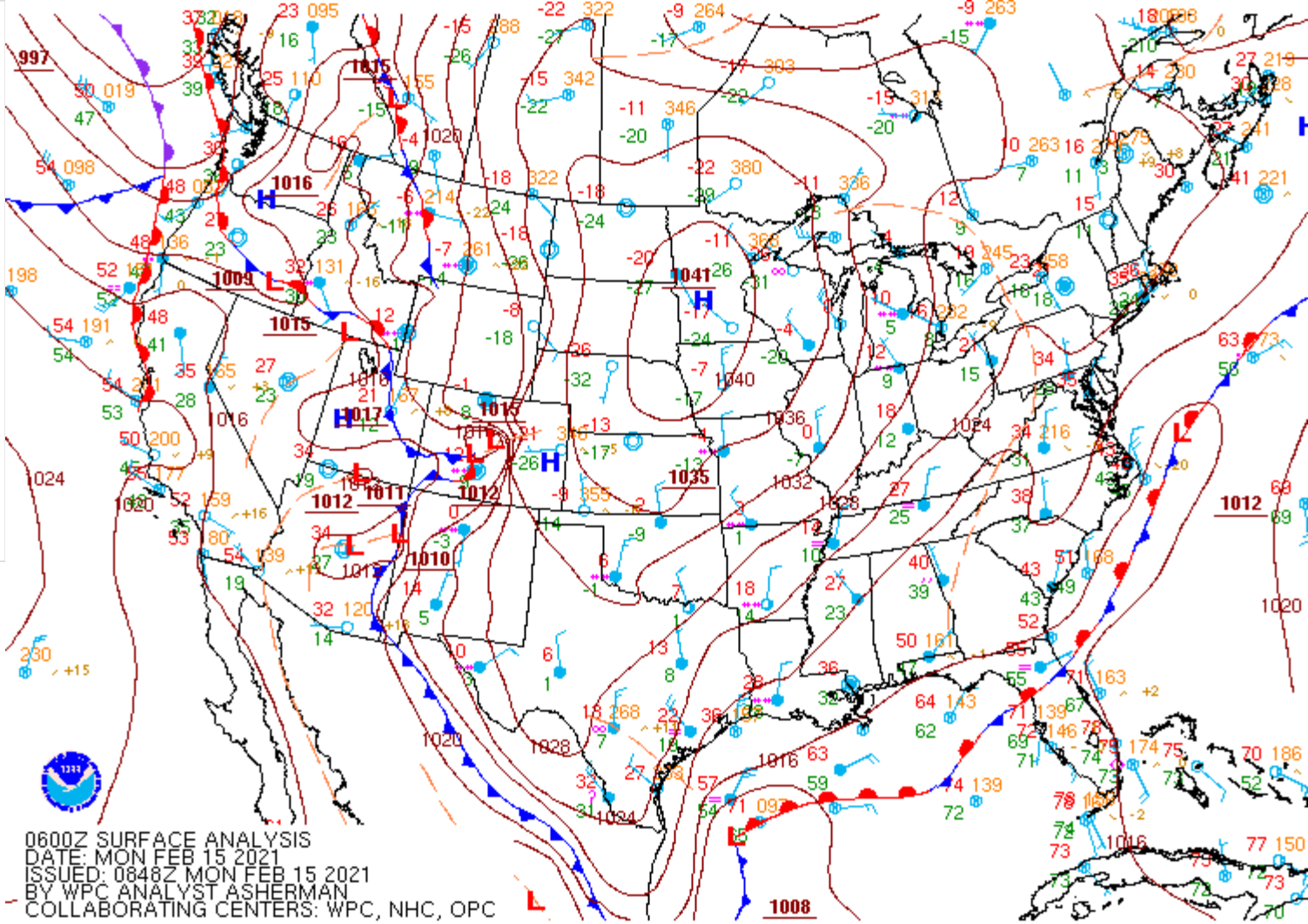


- Uri strengthens somewhat over Gulf
- Enhanced gradient yields coldest temperatures yet into SE Texas.
- Dallas now in single digits
- Spiking loads, gas shortages, unscheduled outages due to freezing at thermal plants and some wind outages lead to firm load shedding as demand can longer be met.



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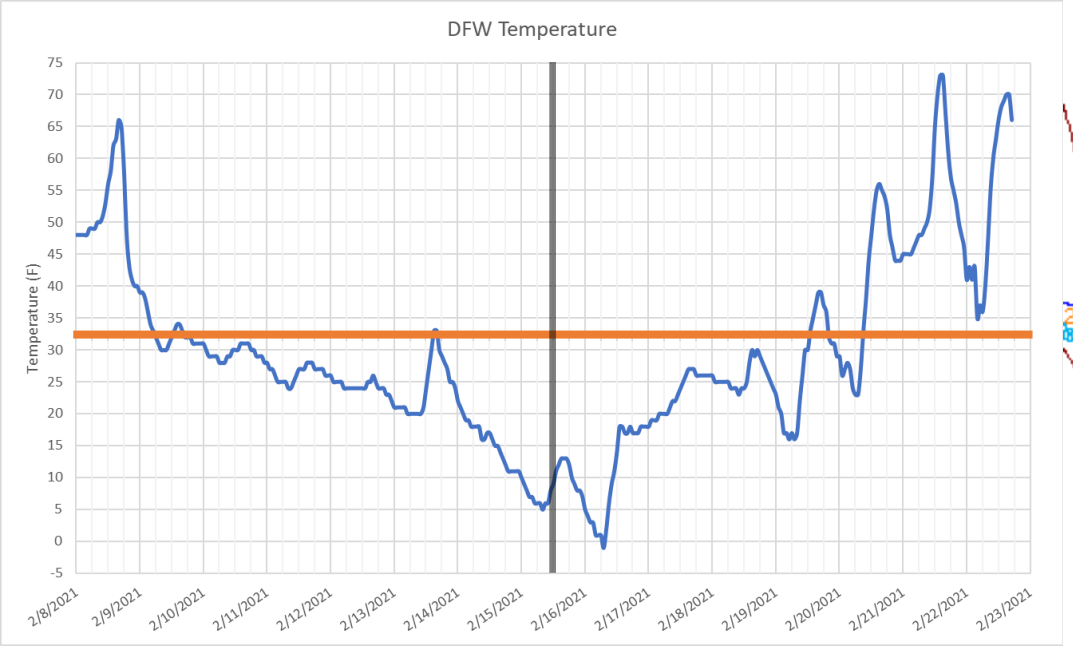
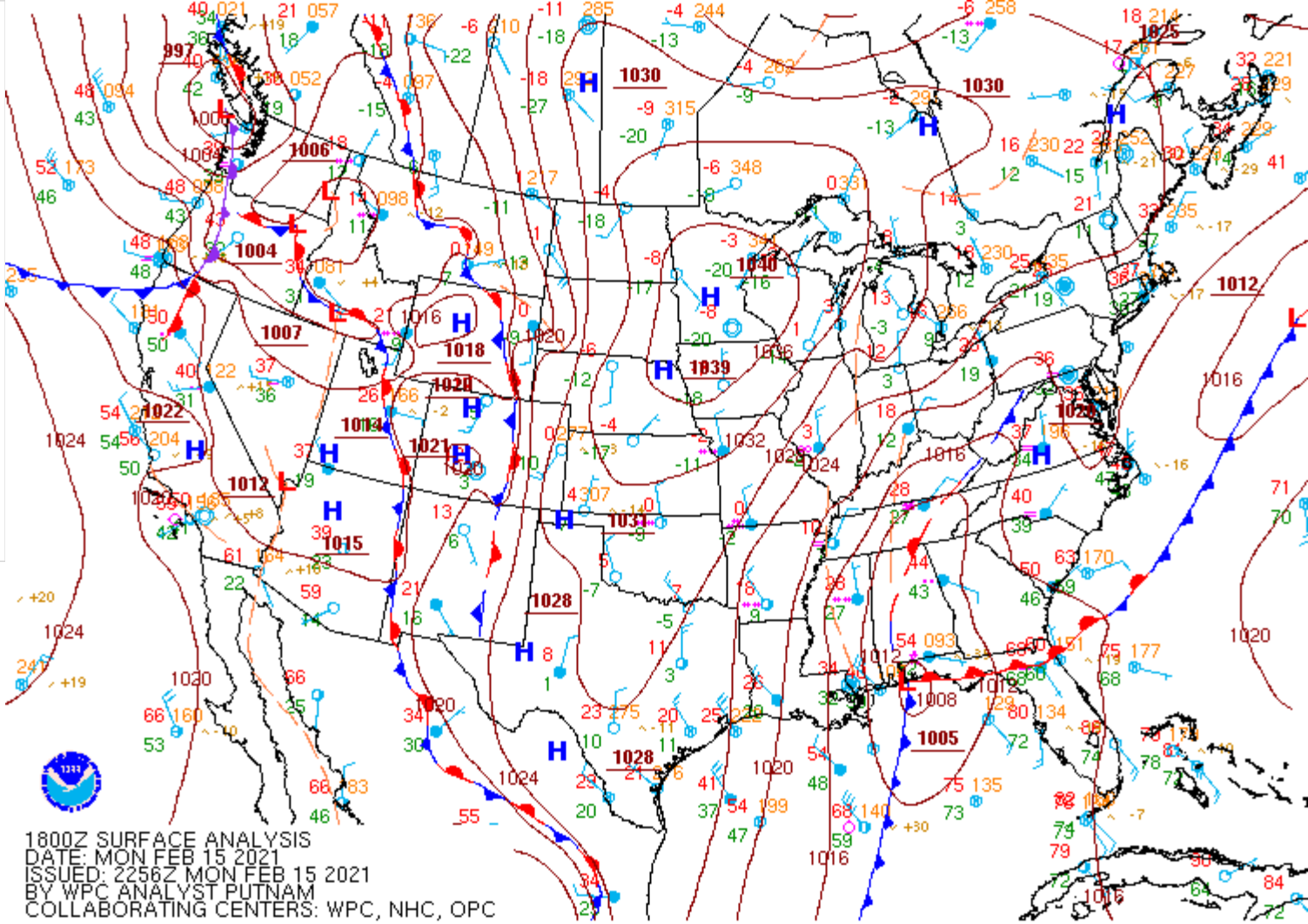


- Uri moves along the South coast
- Despite clearing behind the storm, strong cold air advection in strong northerly winds behind the storm prevents much daytime temperature recovery.
- Next Pacific storm hits the PNW bringing milder temperatures to most of that region, but more freezing rain to sheltered valleys.



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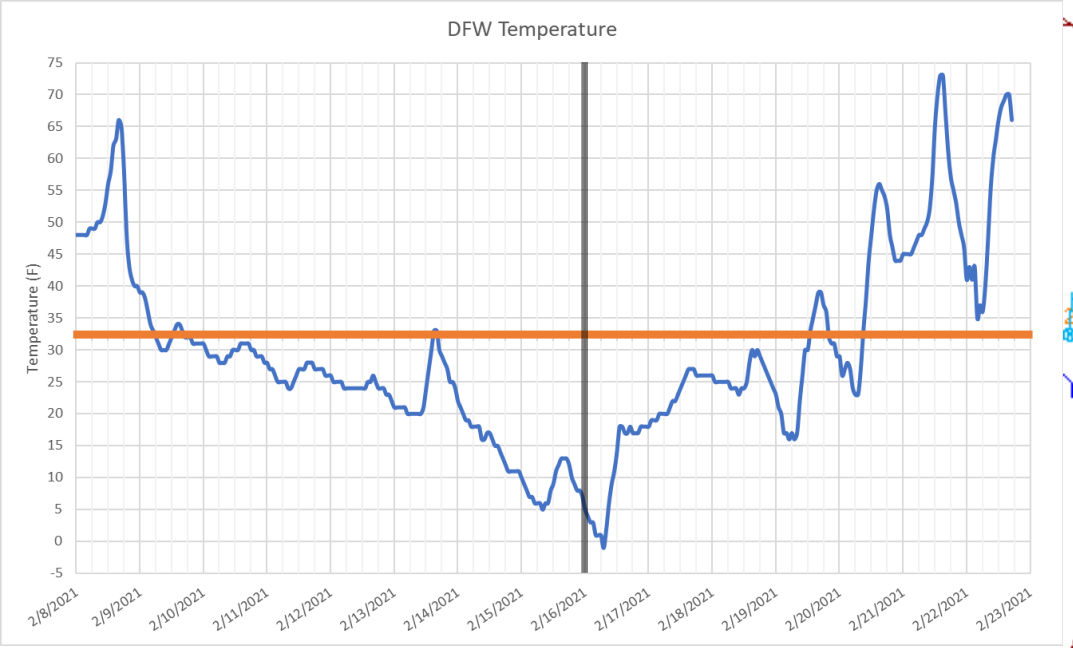
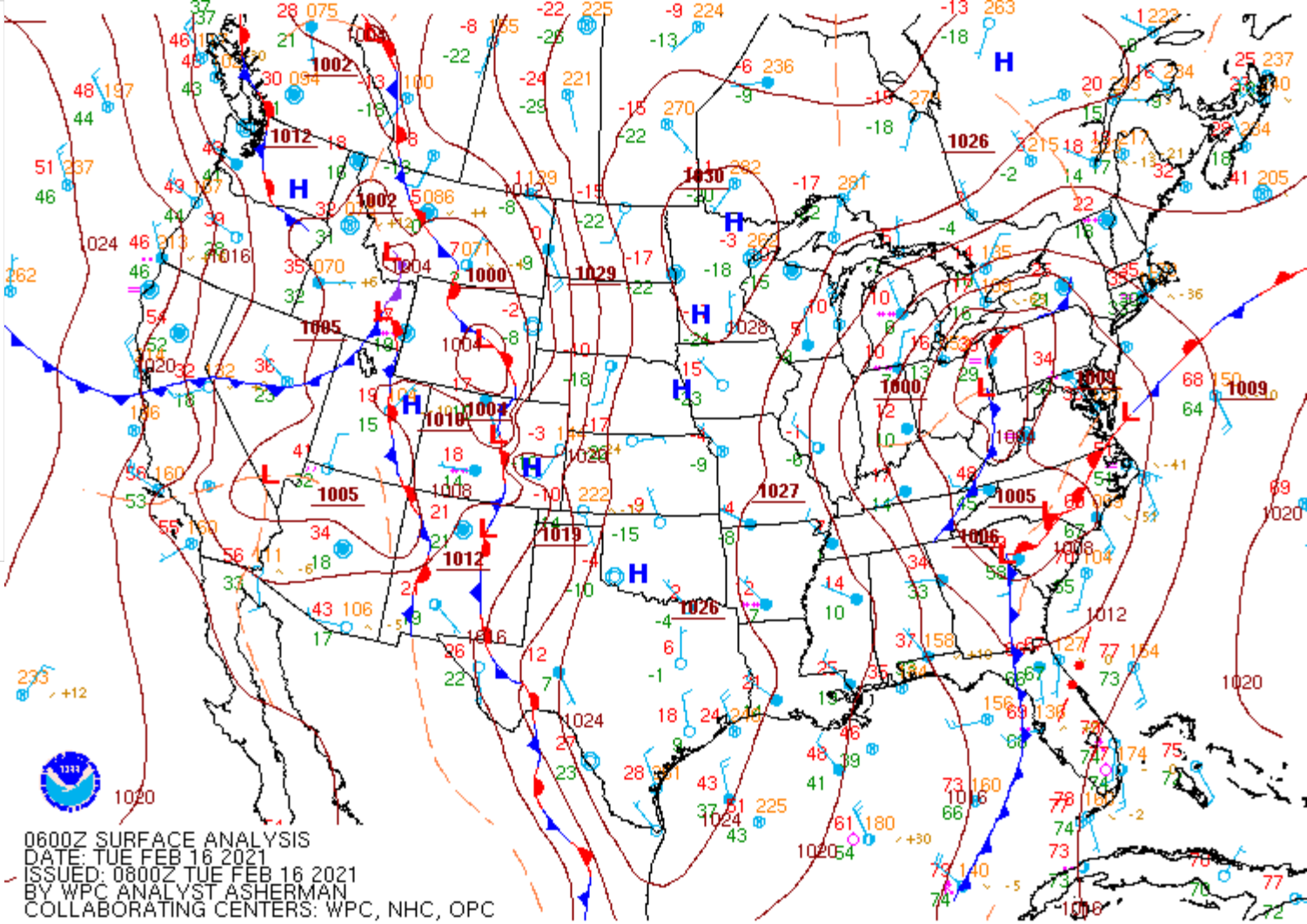


- Clear skies and light northerly winds lead to temperatures crashing across Texas and much of the southern plains
- Many record lows set



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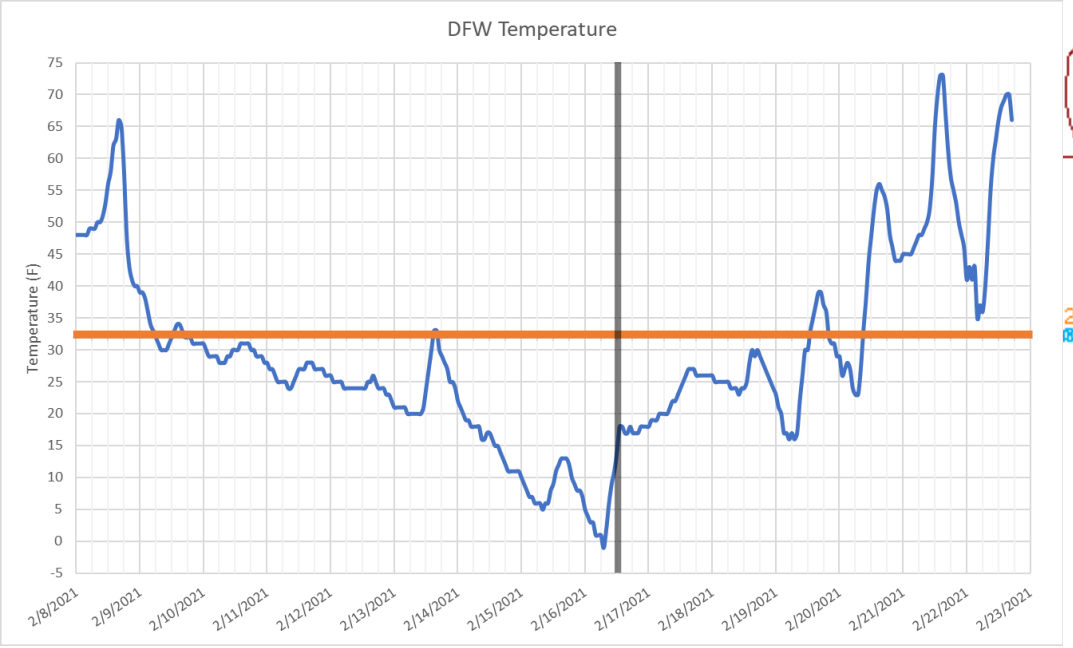
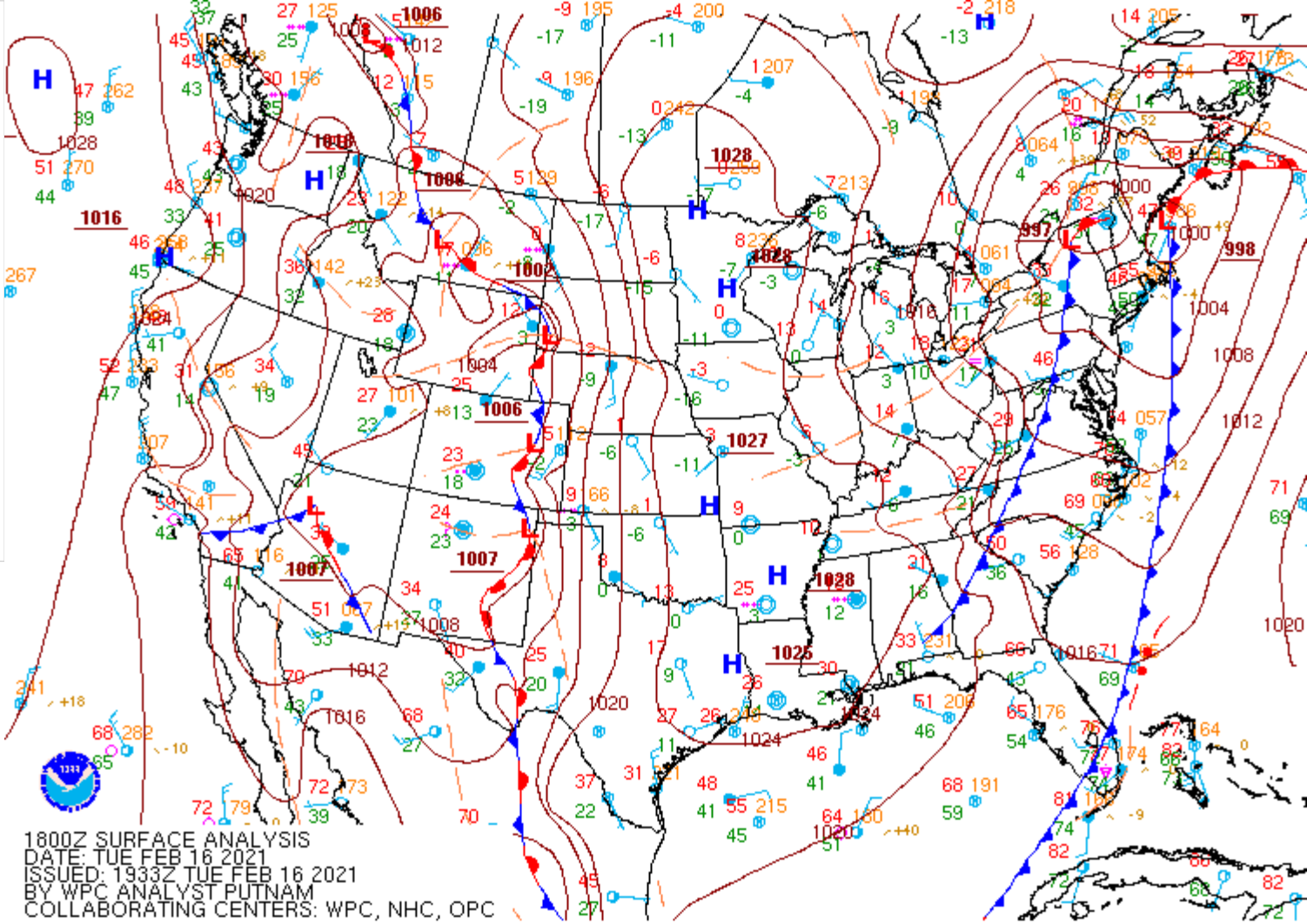


- The pattern begins to translate slowly east
- Deep cold air still in place but winds turn into the south and temperature begins to moderate.
- Uri and Viola impact the east coast.



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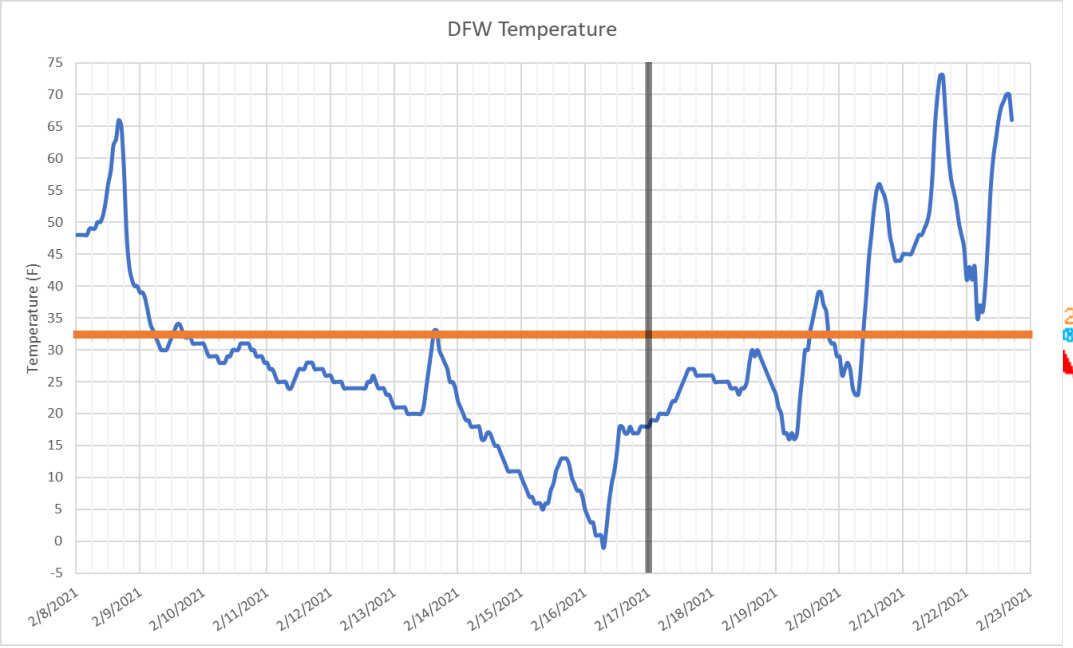
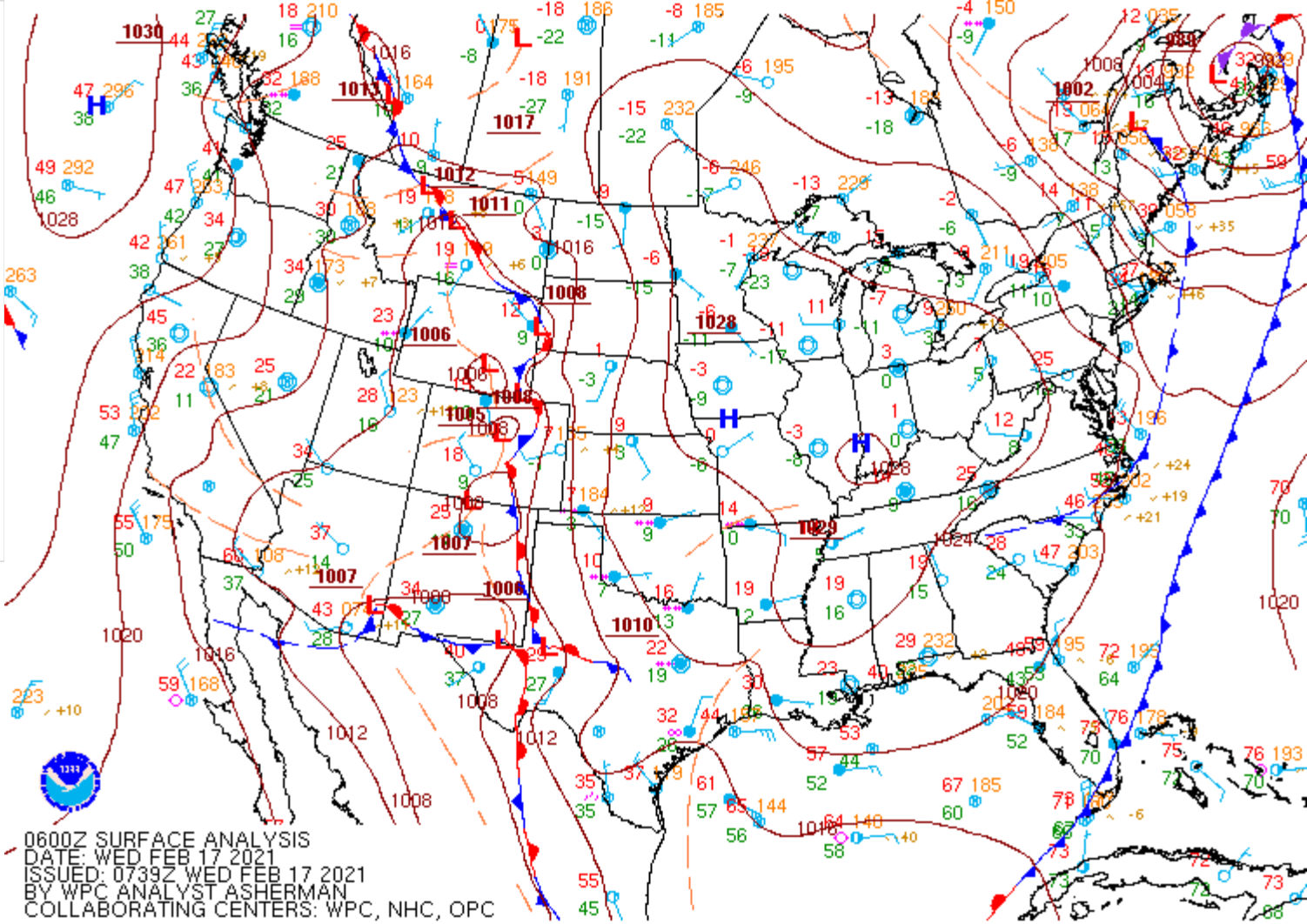


- Continued SLOW moderation
- With snow cover, light winds, and long nights, temperature is slow to recover.
- Note, eastern wind resource is very low and a large area is very cold. This could be a concern in the future as RE penetration increases
  - Josh will discuss this type of scenario.



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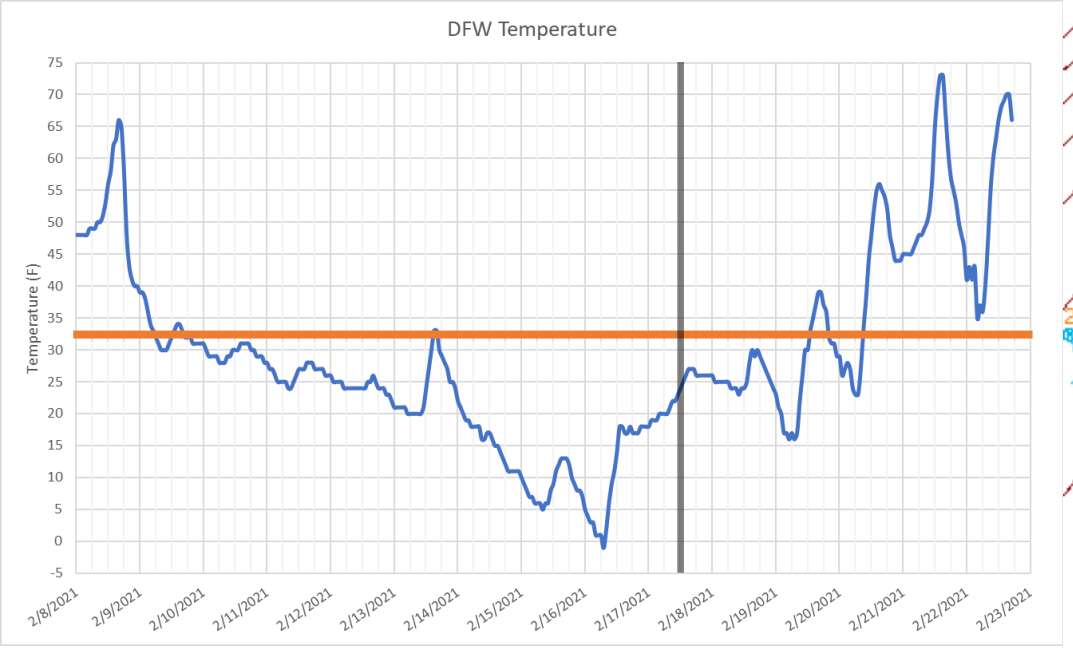
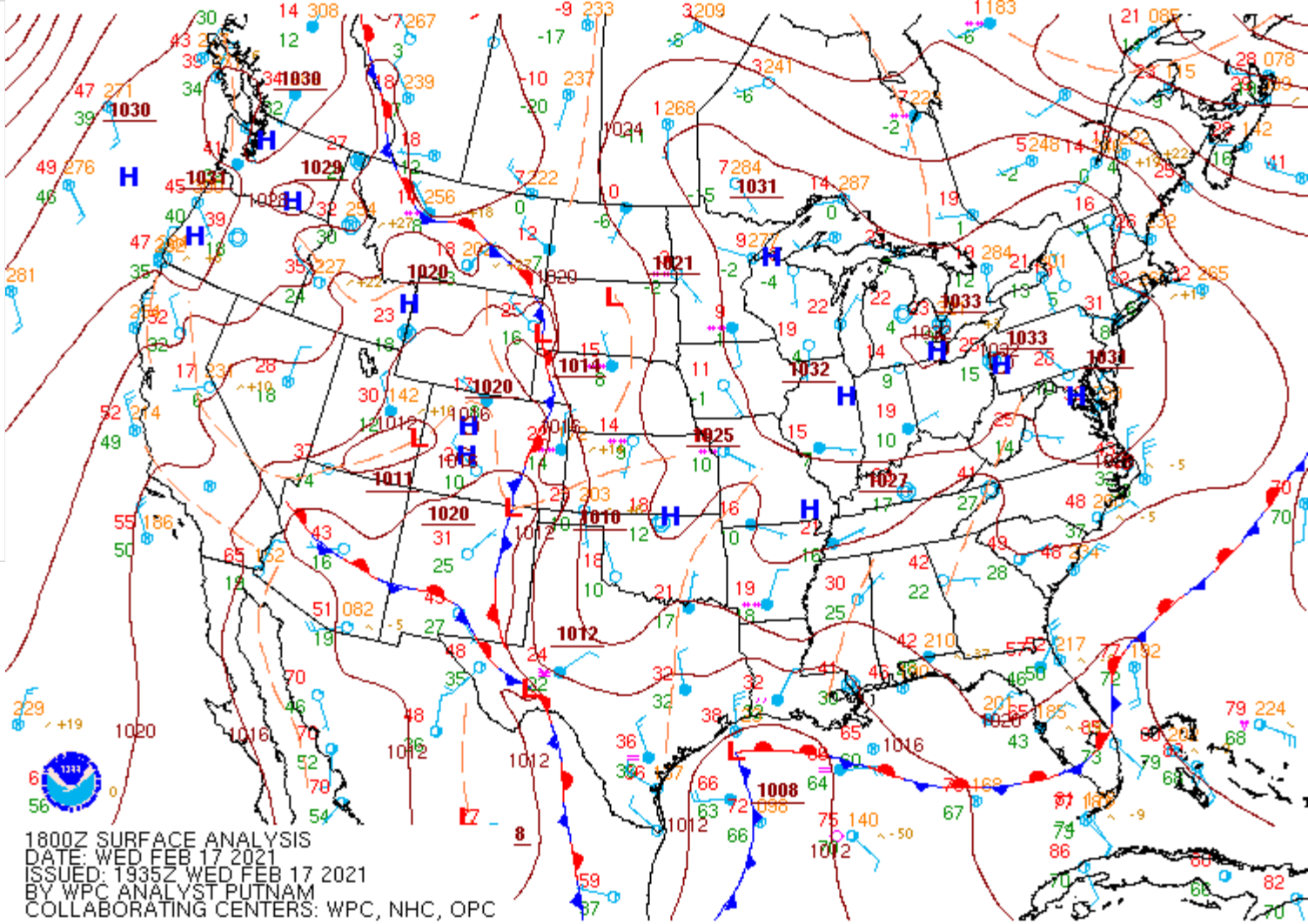


- More of the same
- Weakening high pressure over much of eastern interconnect
- Low wind resource and cloudy skies
- Weak storm forming on coastal boundary slows moderation of cold air in Texas



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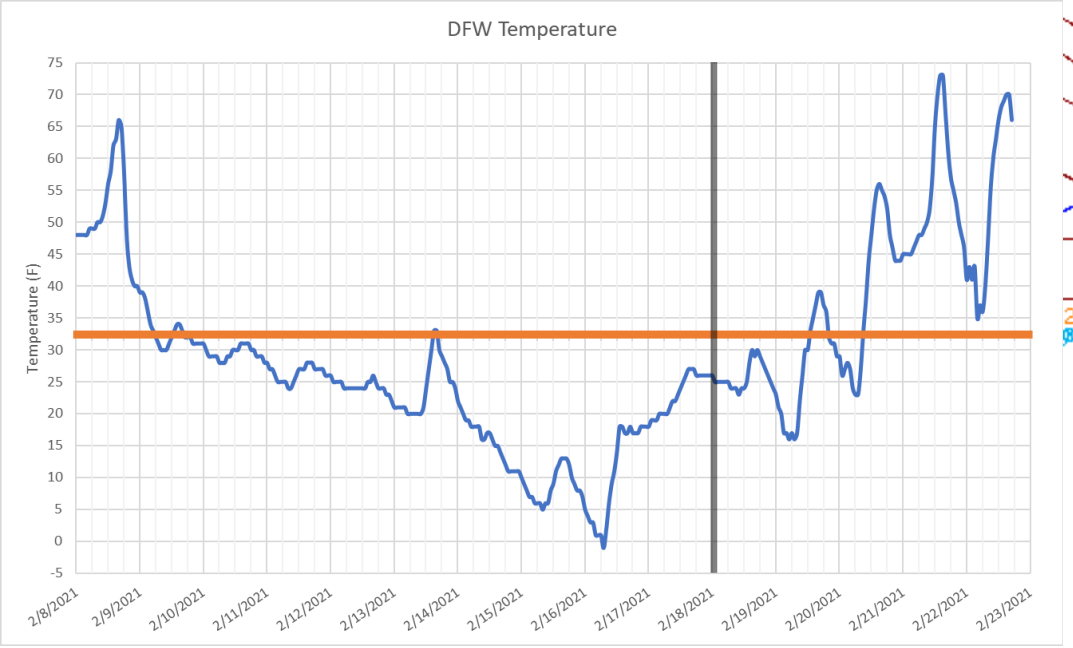
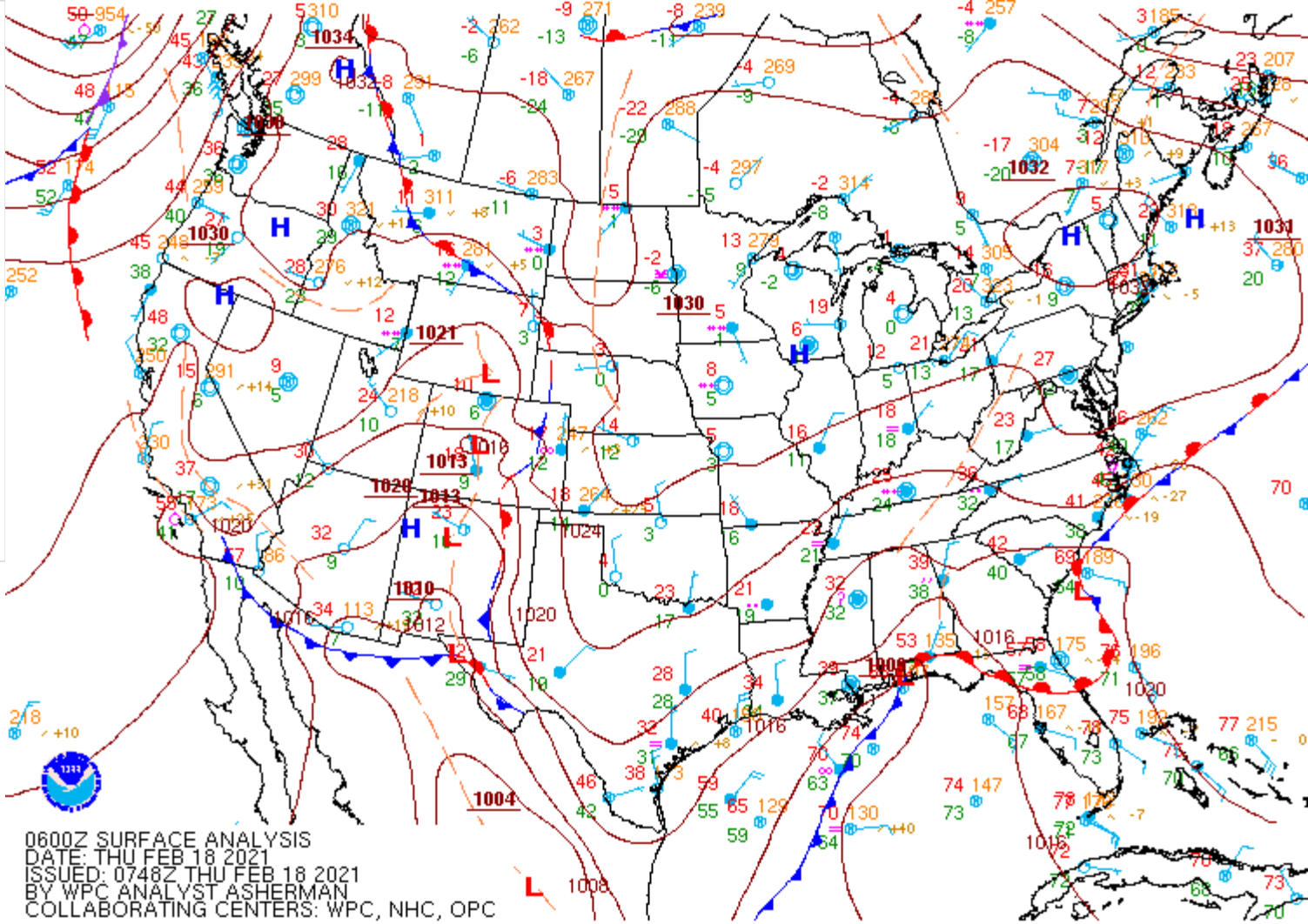


- Continued very slow moderation
- Much of country under weak high pressure
  - Again, see Josh's talk for why we are concerned about this phase of an event like this
  - If pattern panned out a little differently and mid-Atlantic now got very cold this could be problematic



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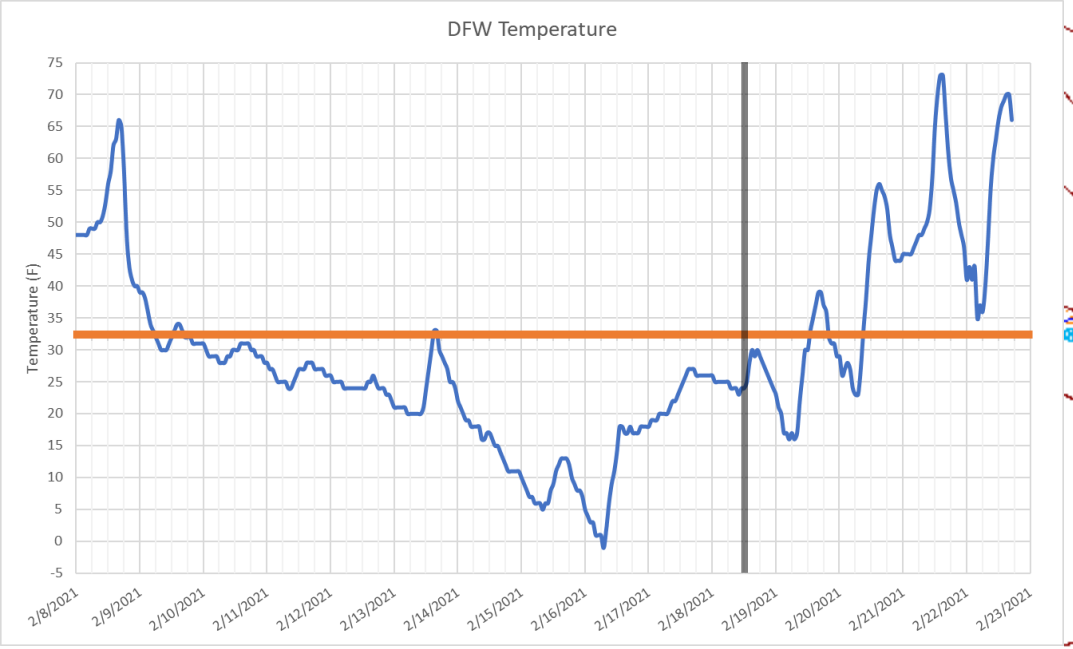
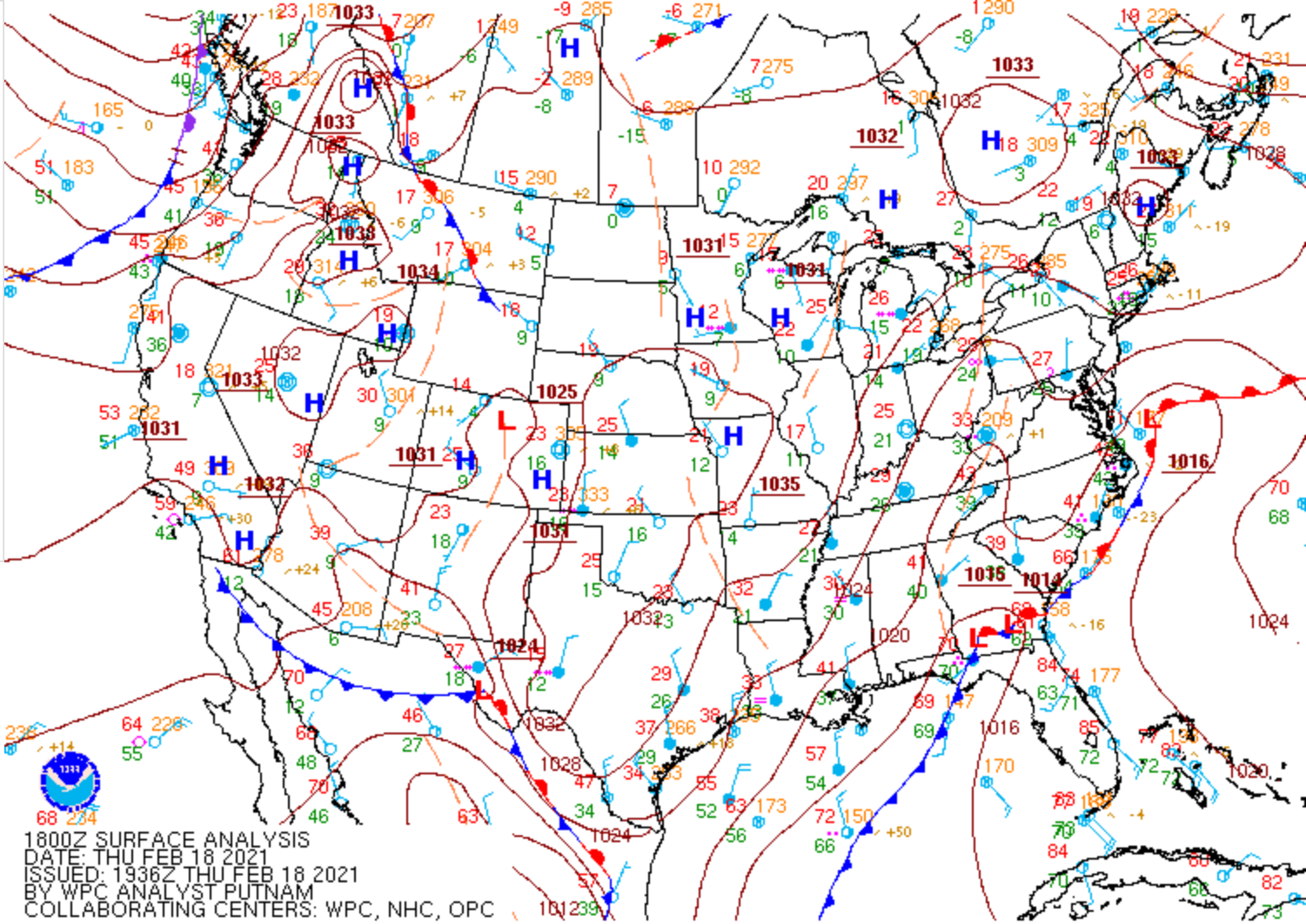


- Back to light northerly winds offsetting daytime warming with cold air across much of south



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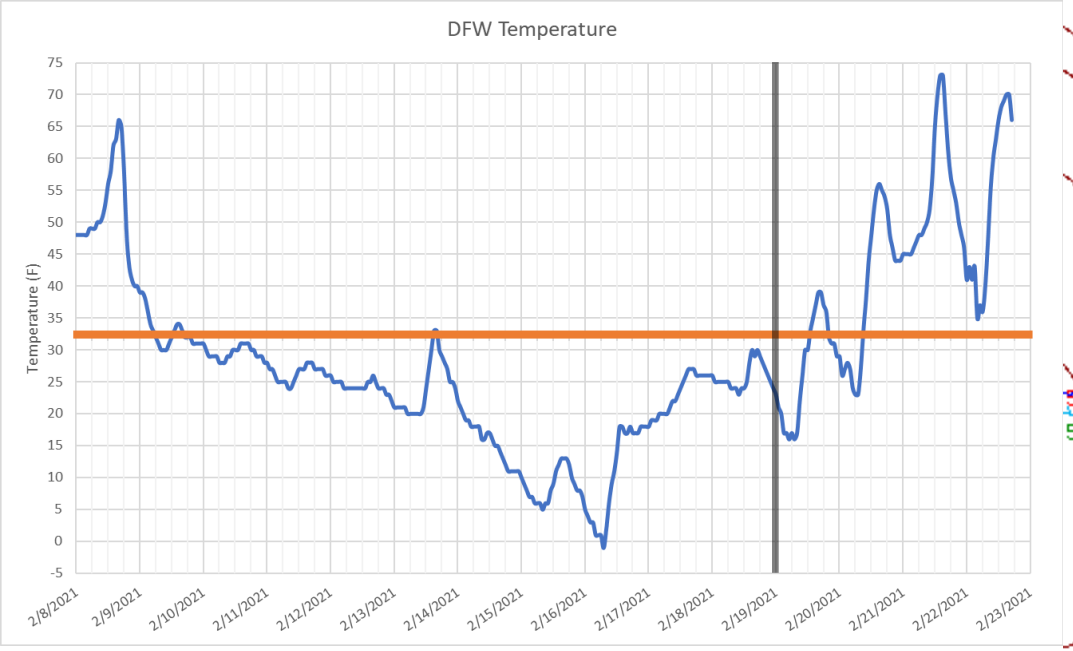
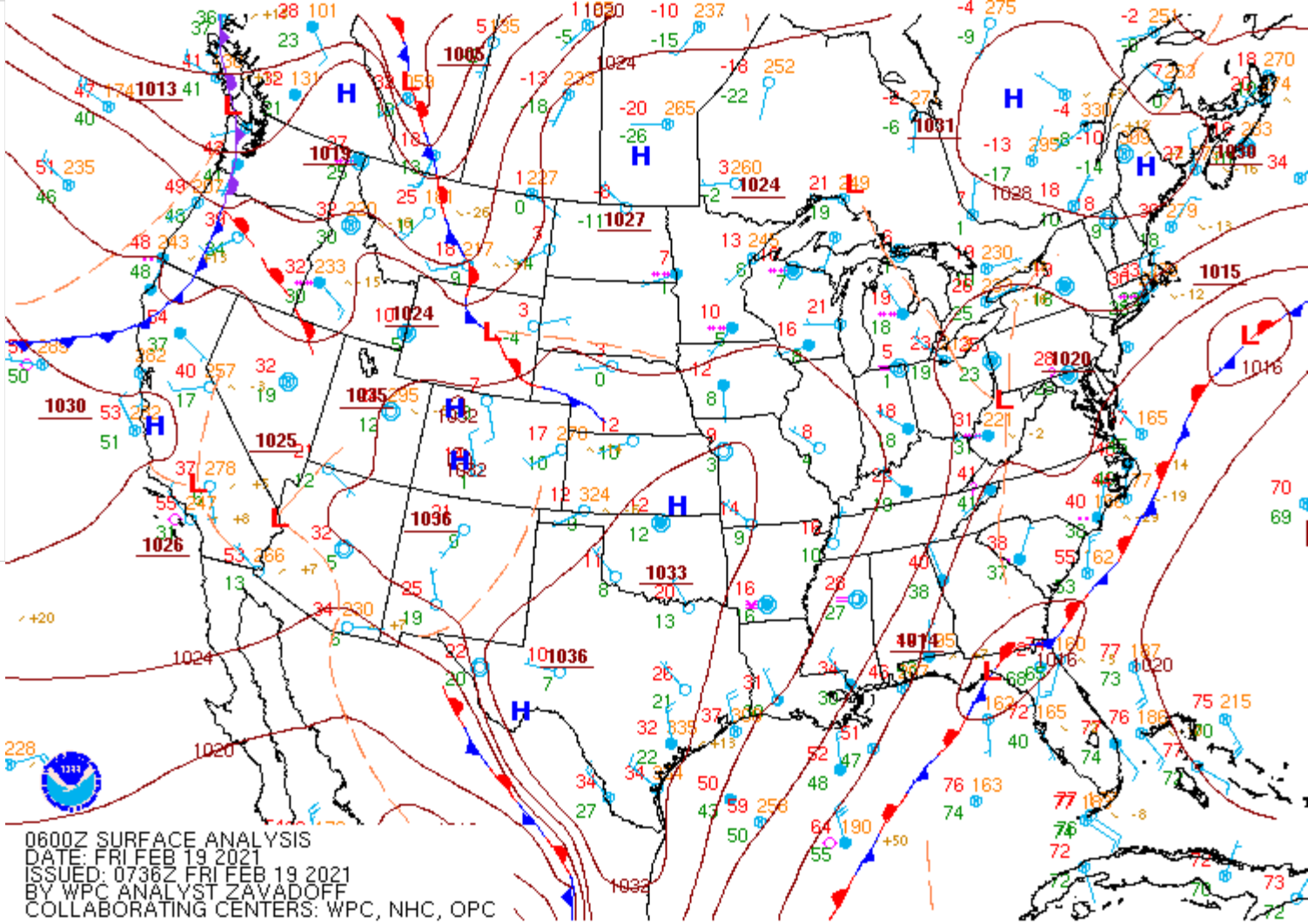
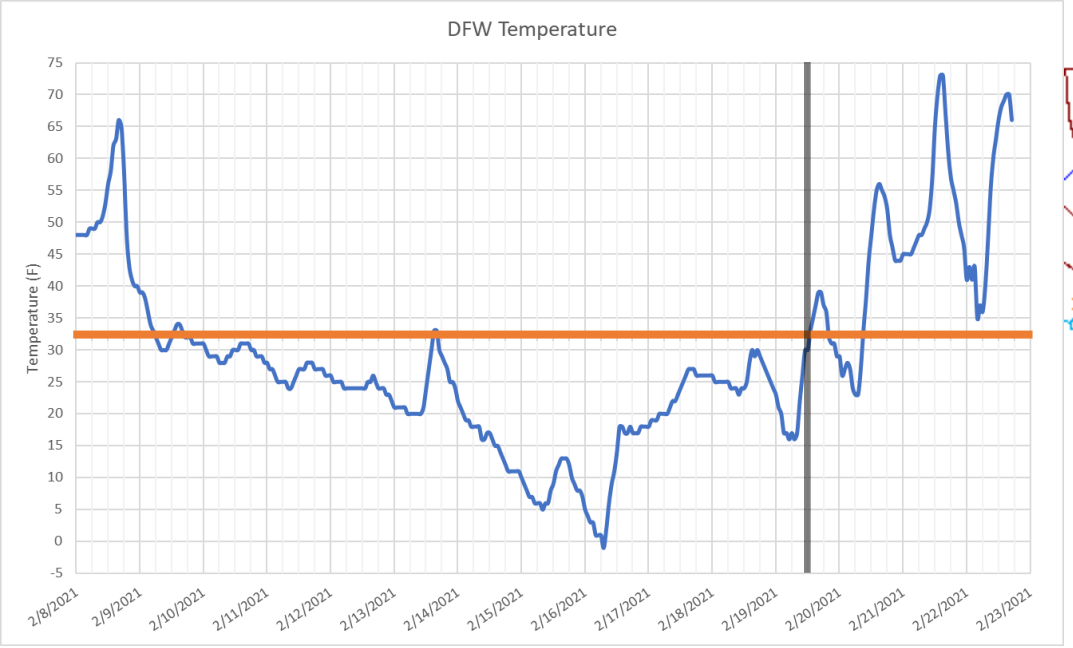


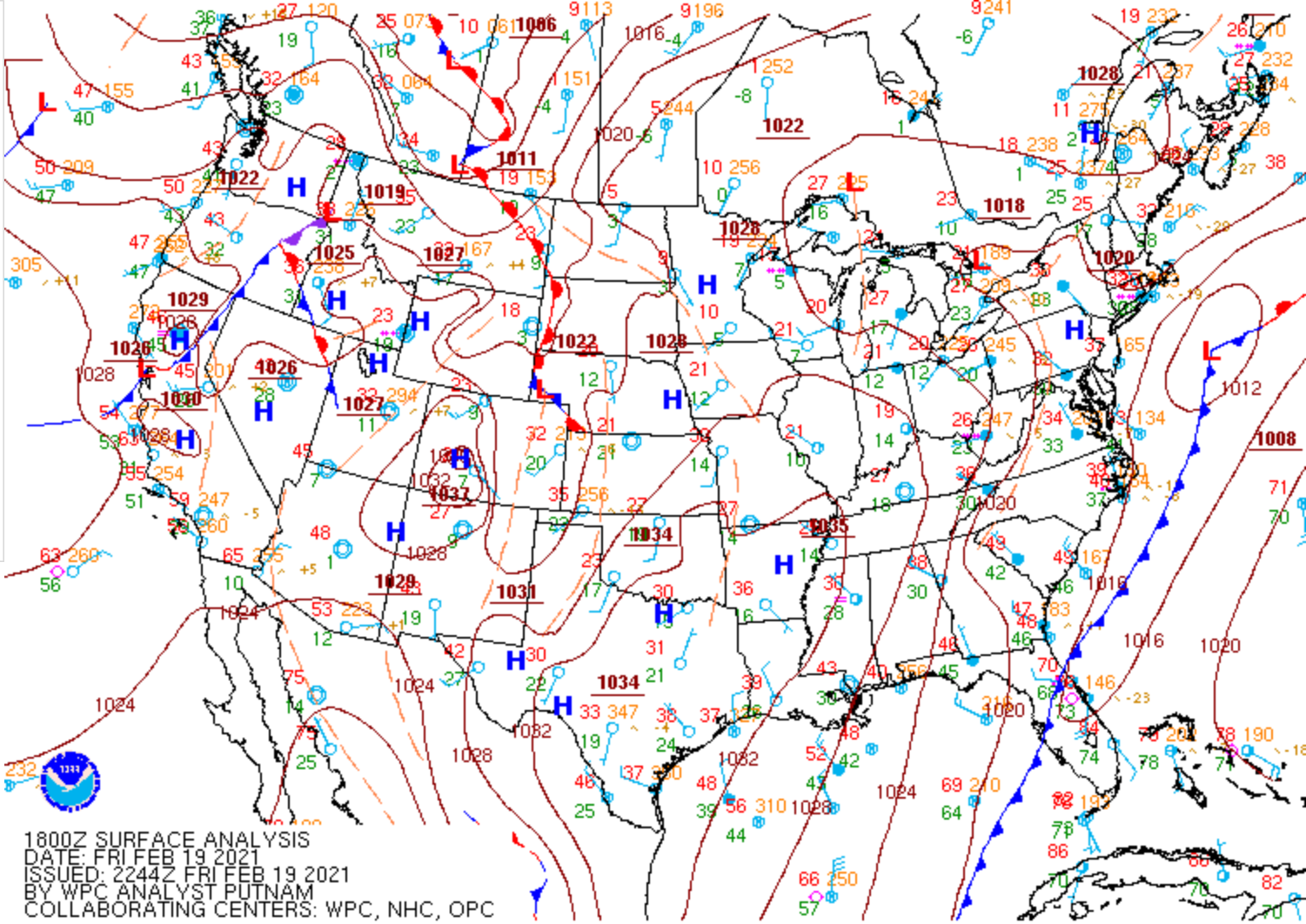
- Under clear skies and light winds temperatures again plummet
- Another day of poor wind resource across a broad area experiencing high loads. Need to examine this phase more closely.



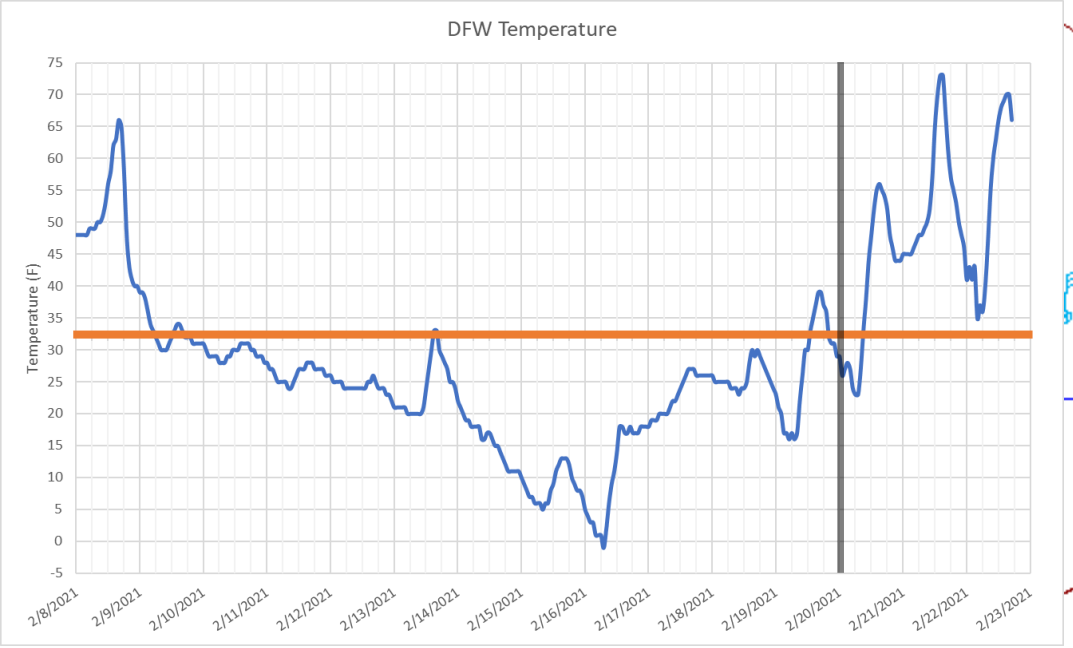
20210219 00 CST Surface Map



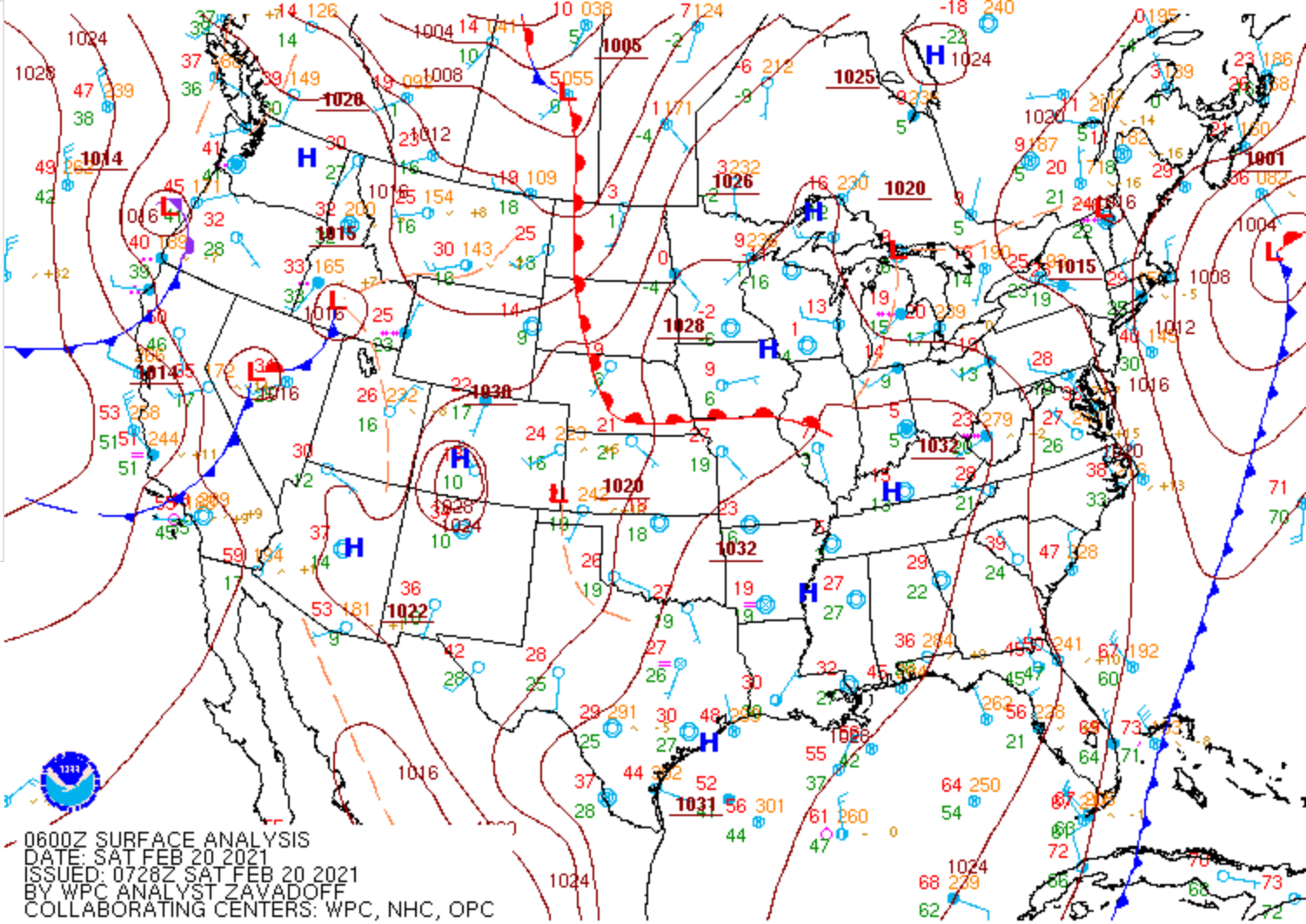
- Under clear skies most of Texas finally breaks freezing
- Continued long duration cold and weak wind resource across large part of EI.



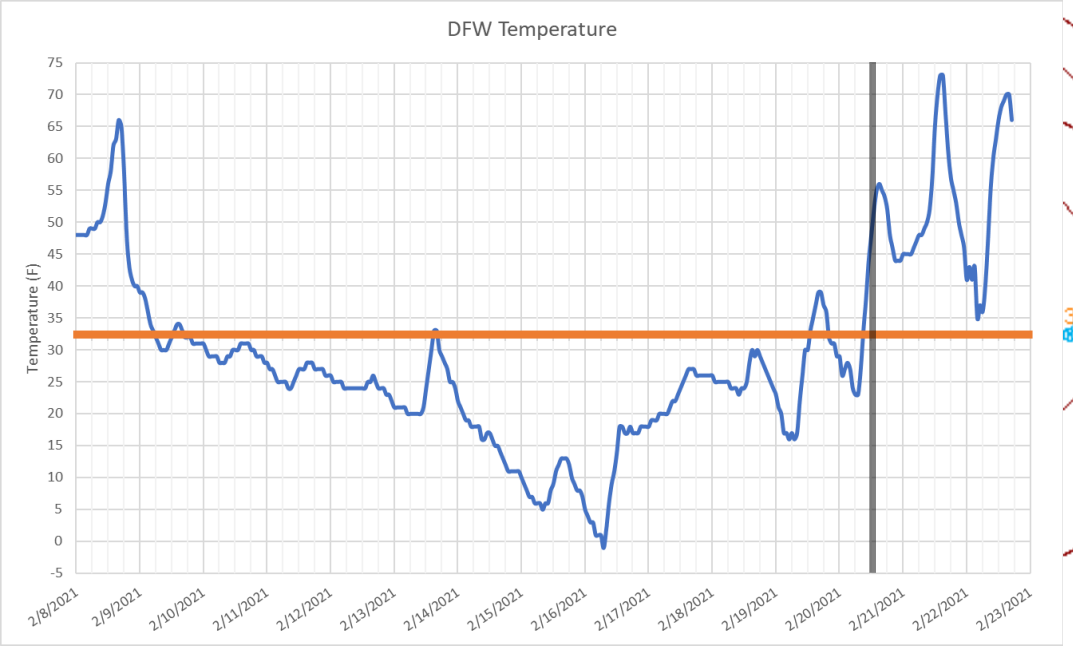
20210219 12 CST Surface Map



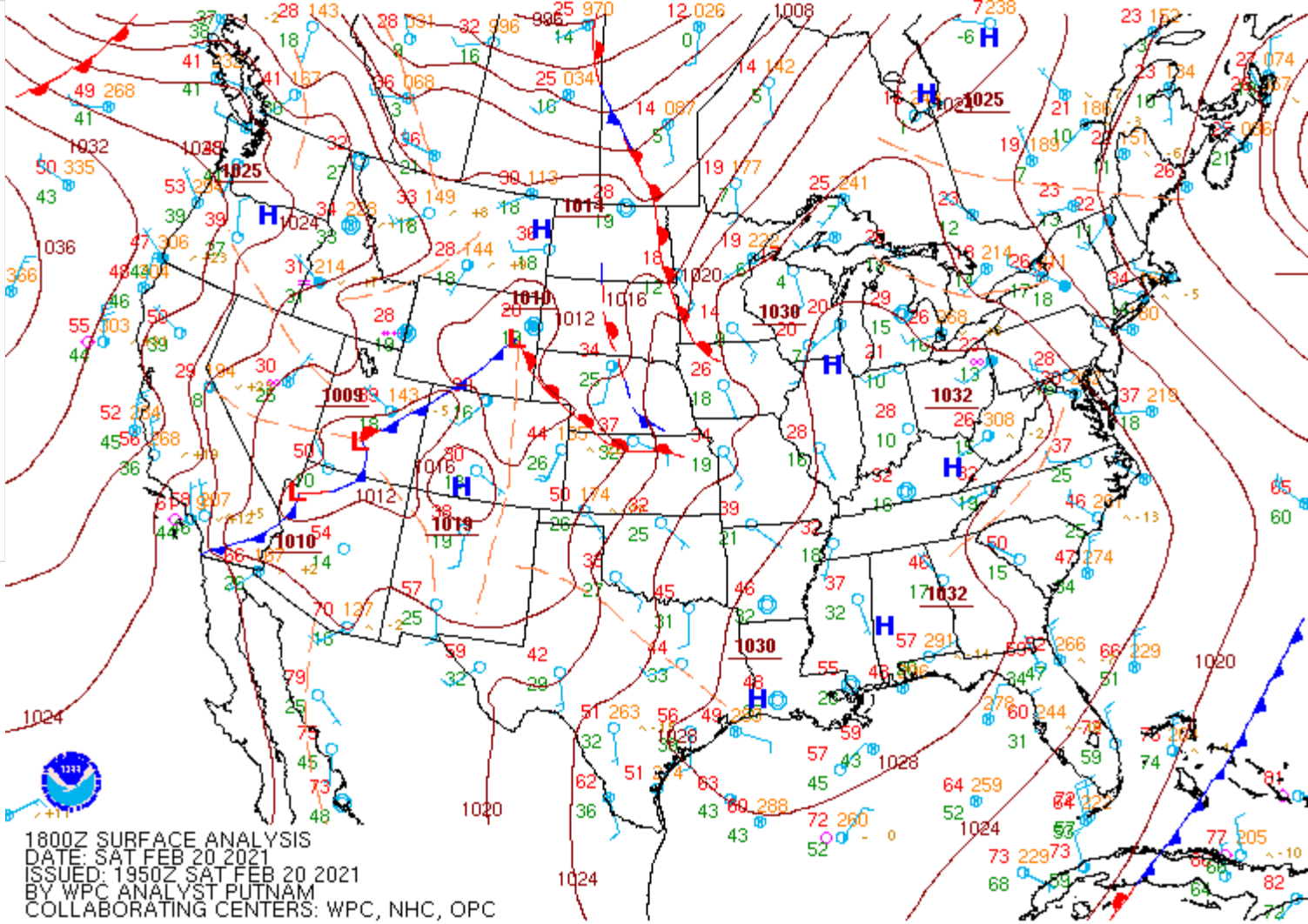
- One last night of freezing temperatures in Texas and much of the south under clear skies, snow cover and low winds.



20210220 00 CST Surface Map



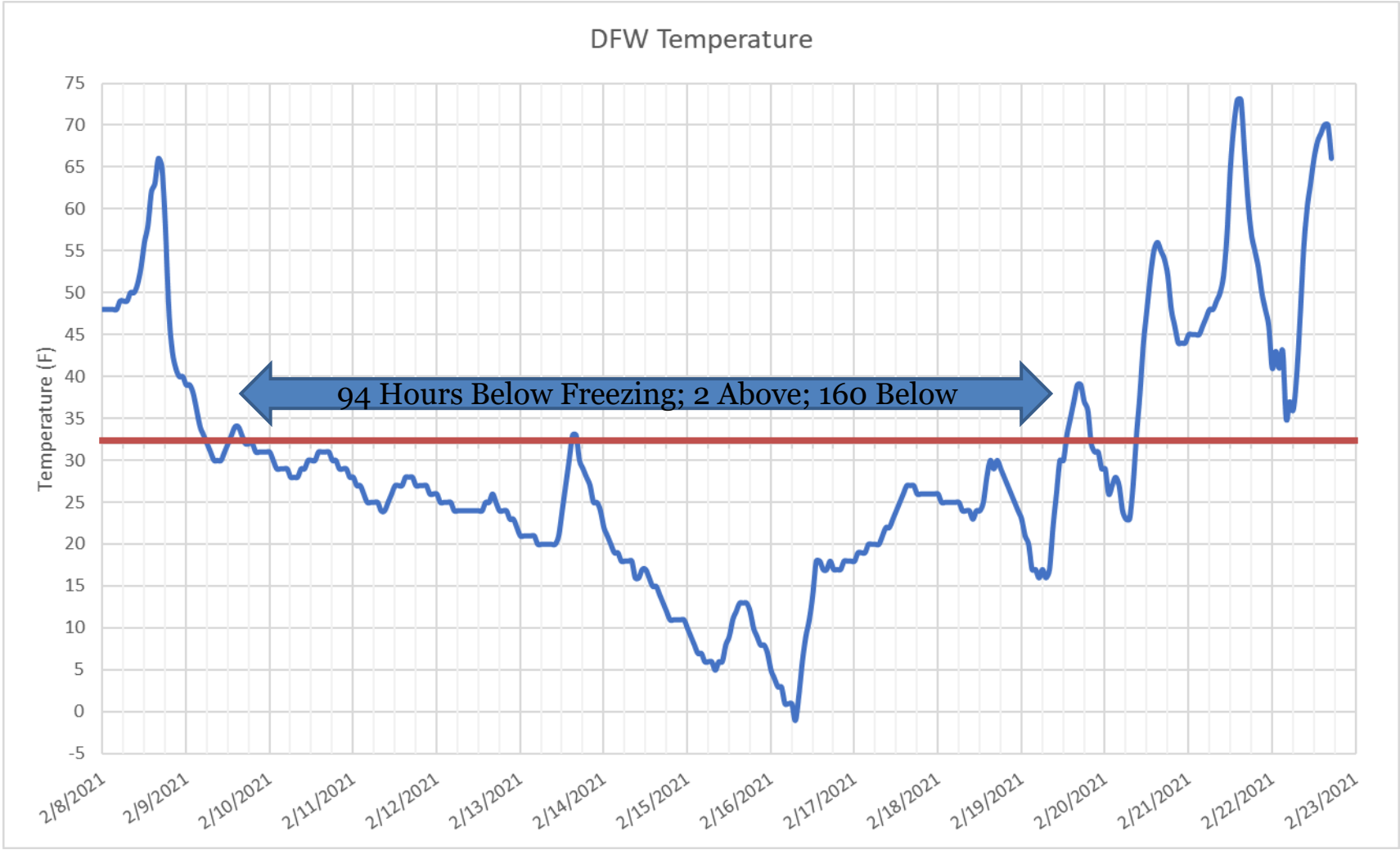
- The pattern finally shifts, and the storm track becomes more progressive again.
- High pressure shifts east, and southerly winds quickly warm the south back to more typical temperatures.



20210220 12 CST Surface Map

How Bad Was It? And How Unusual? Let's Look At Dallas First

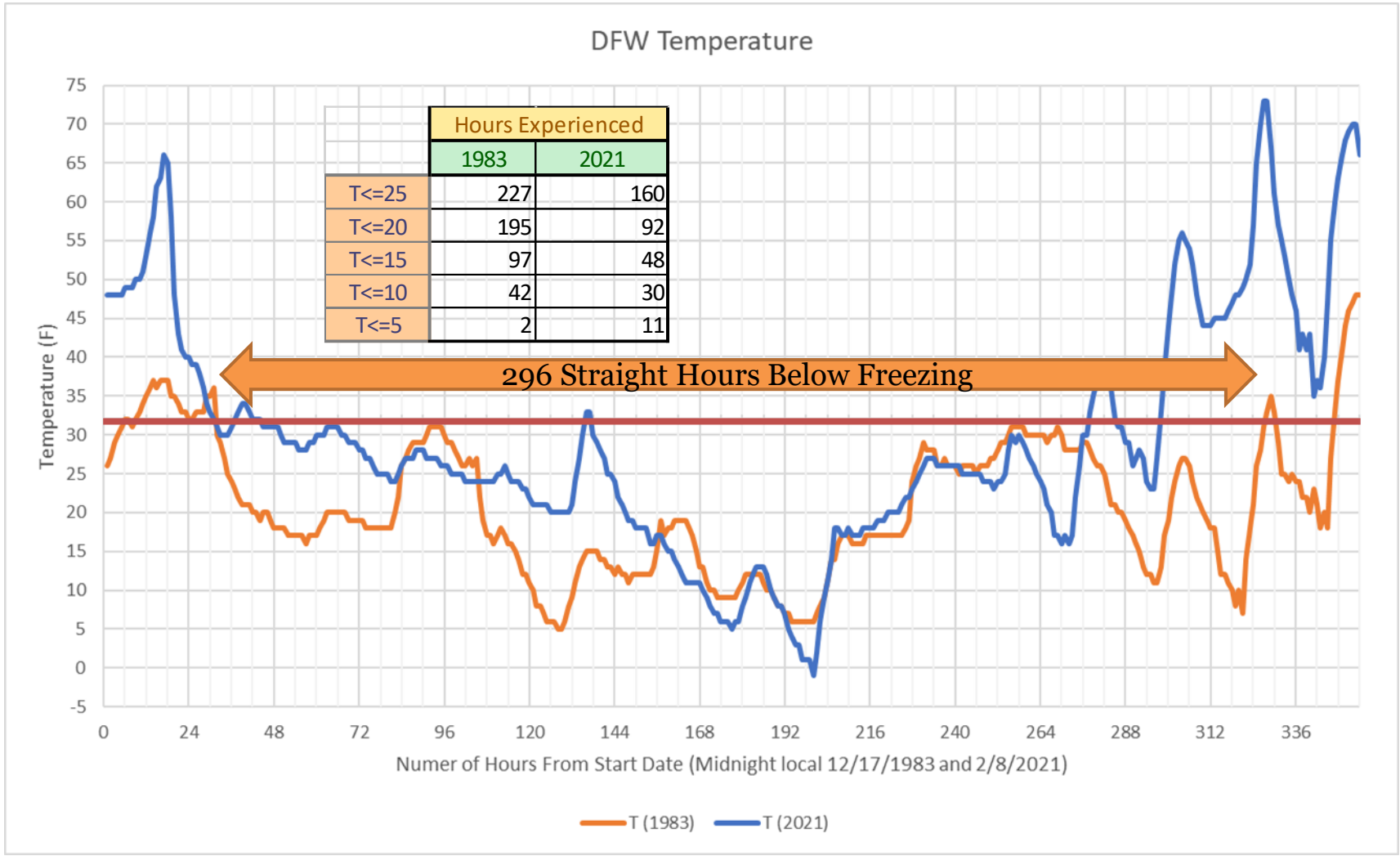
- Extremely Unusual
  - Duration
  - Southerly extent
  - Severity



How Bad Was It? And How Unusual? Let's Look At Dallas First

- Extremely Unusual
  - Duration
  - Southerly extent
  - Severity

- But NOT Unprecedented
  - Cold for longer in 1983
  - Not quite as cold in the extremes, but overall, more total area below freezing in the graph



Comparison of Long-Lived Cold Events at Three Texas Stations

- Looked for days meeting the following condition:
  - Dallas: Tmax <= 32 F and Tmin <= 25 F for a minimum of three consecutive days (1948-present)
  - Houston: Tmax < 35 F and Tmin <= 30 F for a minimum of two consecutive days (1931-present)
    - February 2021 Didn't make the list! The max was too warm.
  - McCallen: Tmax < 40 F and Tmin <= 32 F for a minimum of two consecutive days (1942-present)

Dallas Fort Worth

Dates	Min High	Min Low	Days <=25	Days <=20	Consecutive Freeze	Notes
Jan 24-Jan 29, 1948	21	11	2	0	10	
Jan 29-Jan 31, 1949	20	-2	2	1	10	
Jan 28-Feb 2, 1951	18	6	4	2	8	
Jan 8-Jan 11, 1973	23	8	1	0	9	*1
Jan 17-Jan 22, 1978	26	13	0	0	16	*2
Dec 19-Dec 29, 1983	13	5	5	4	17	*3
Jan 31-Feb 4, 1985	17	7	2	1	10	
Jan 7-Jan 9, 1988	29	16	0	0	12	
Feb 3-Feb 6, 1989	18	13	2	1	9	
Dec 21-Dec 23, 1989	14	-1	2	1	15	
Feb 1-Feb 4, 1996	27	8	0	0	7	
Jan 11-Jan 14, 1997	23	18	2	0	12	
Feb 2-Feb 4, 2011	20	13	2	1	5	
Feb 10-Feb 18, 2021	14	-2	6	3	12	*4

Houston

Dates	Min High	Min Low	Days <=30	Days <=25	Consecutive Freeze
Feb 8-Feb 9, 1933	34	15	0	0	2
Jan 28-Jan29, 1948	32	26	0	0	5
Jan 29-Jan 30, 1949	29	12	1	0	4
Jan 30-Feb 2, 1951	25	14	4	1	6
Jan 10-Jan 11, 1962	29	17	2	0	5
Jan 19-Jan 21, 1978	30	24	1	0	4
Dec 22-Dec 26, 1983	27	13	2	0	11
Feb 4-Feb 7, 1989	28	25	1	0	6
Dec 22-Dec 23, 1990	31	23	0	0	4

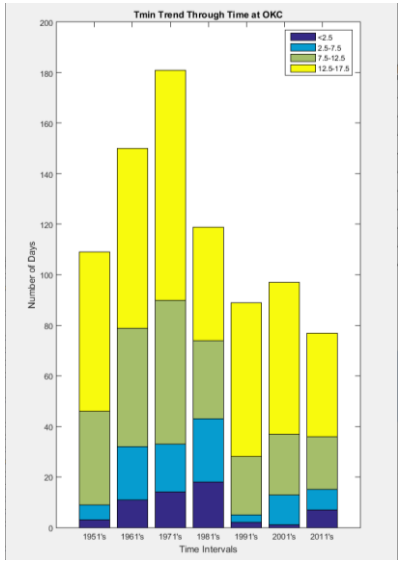
McCallen

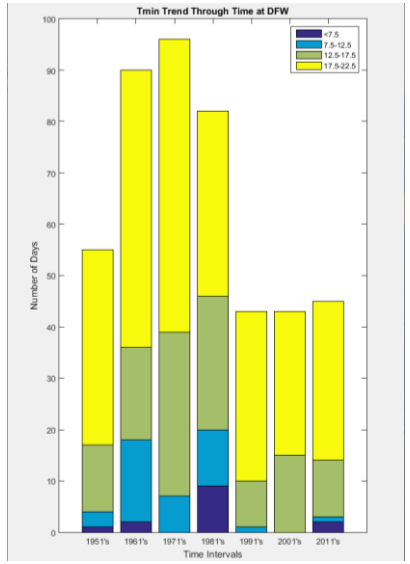
Dates	Min High	Min Low	Days <=35	Days <=30	Consecutive Freeze
Jan 28-Jan29, 1948	32	28	1	0	5
Jan 30-Feb 1, 1951	29	21	2	1	4
Jan 10-Jan 11, 1962	31	22	2	0	3
Jan 10-Jan 11, 1973	35	30	0	0	4
Dec 25-Dec 27, 1983	29	18	2	1	7
Jan 13-Jan 14, 1985	35	30	2	0	1
Feb 5-Feb 7, 1989	33	30	1	0	3
Dec 23-Dec 24, 1989	29	18	2	1	4
Jan 14-Jan 15, 1997	33	30	1	0	3
Feb 15-Feb 16, 2021	38	20	0	0	4

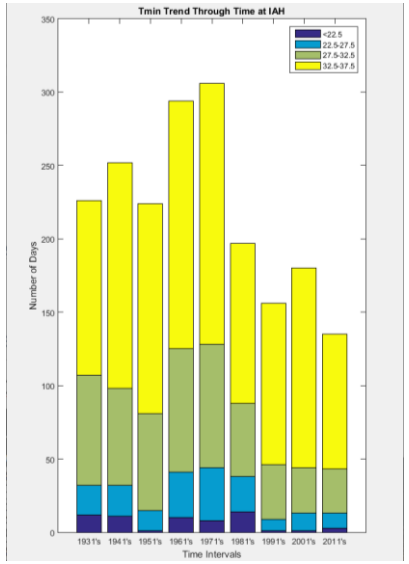
*1: 22 years since last low in single digits
*2: Cold overall year
*3: 32 years since last high in the teens. Cold Season: Jan 1984 was cold too
Lowest high in current record, though 1899 was colder.
*4: 32 years since last high in the teens. Most days<25F

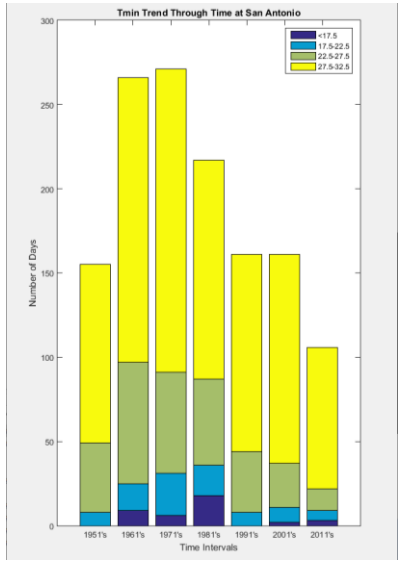
What About Climate Change? Are These Events Becoming More Common?

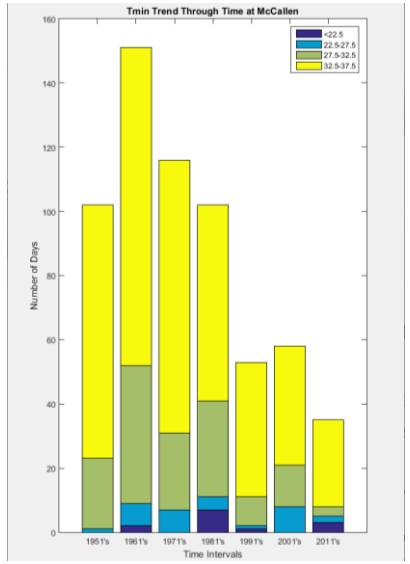
- Data for each decade was binned and plotted for daily max and min at low end of temperature distribution
- Data is noisy but suggests a decline in incidence of very cold min and max days
- Hard to tease out climate signal from decadal variability but does not suggest events are becoming more common.
- Note: Decades go from Fall ccD1 to Summer cc(D+1)1 to capture contiguous winter seasons.

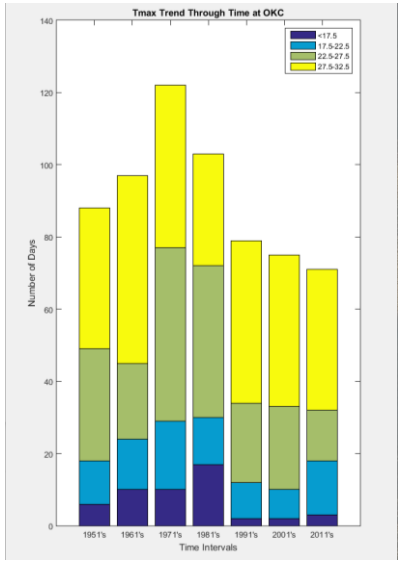


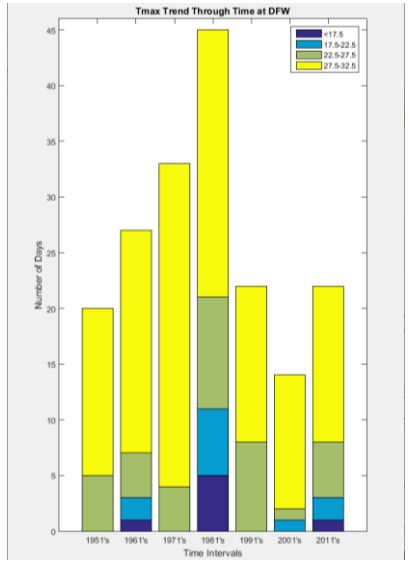


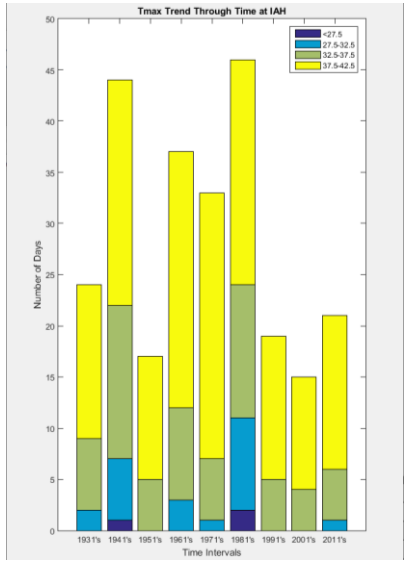


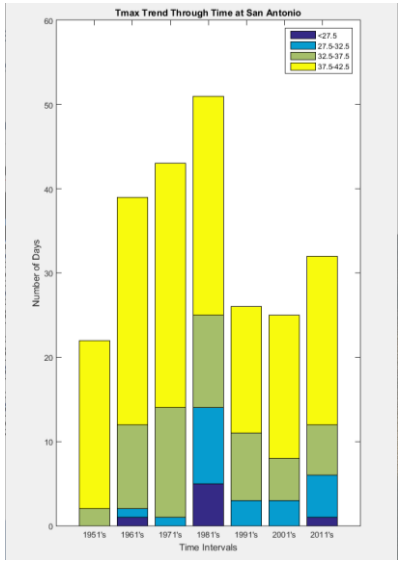


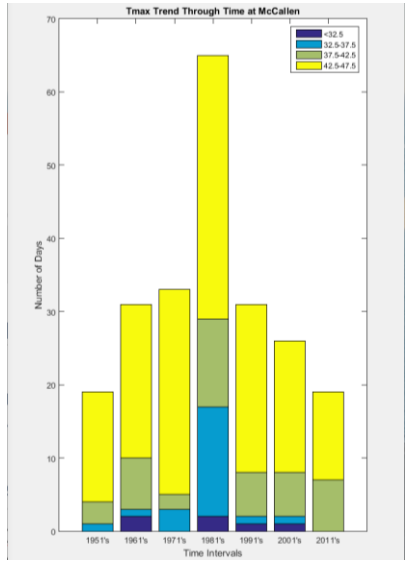












Conclusions

- The February 2021 Cold Wave WAS a tail event for Texas. However, it was NOT unprecedented. Nor was it the most extreme event seen in the state. It was arguably one of the top handful of events since records began.
- Many records were set, but many others remain standing. It was NOT an act of god that cannot be planned for.
- Such events appear to have a return frequency of about 20 to 35 years. Their recurrence also seems to be correlated with periods of several years that exhibit generally more extreme winter temperatures
- There is NO apparent climate change signal in the data. Indeed, the data suggests that natural variability on the decadal scale drives the events and that their overall intensity may be diminished slightly by climate change
- Overall frequency of extreme cold appears to be diminishing, but the frequency of the most extreme events may not be…by their nature the sample size is too small to be definitive.