Toward Better Operational Predictions of High-Impact Winter Weather in the Northern High Plains and Rockies

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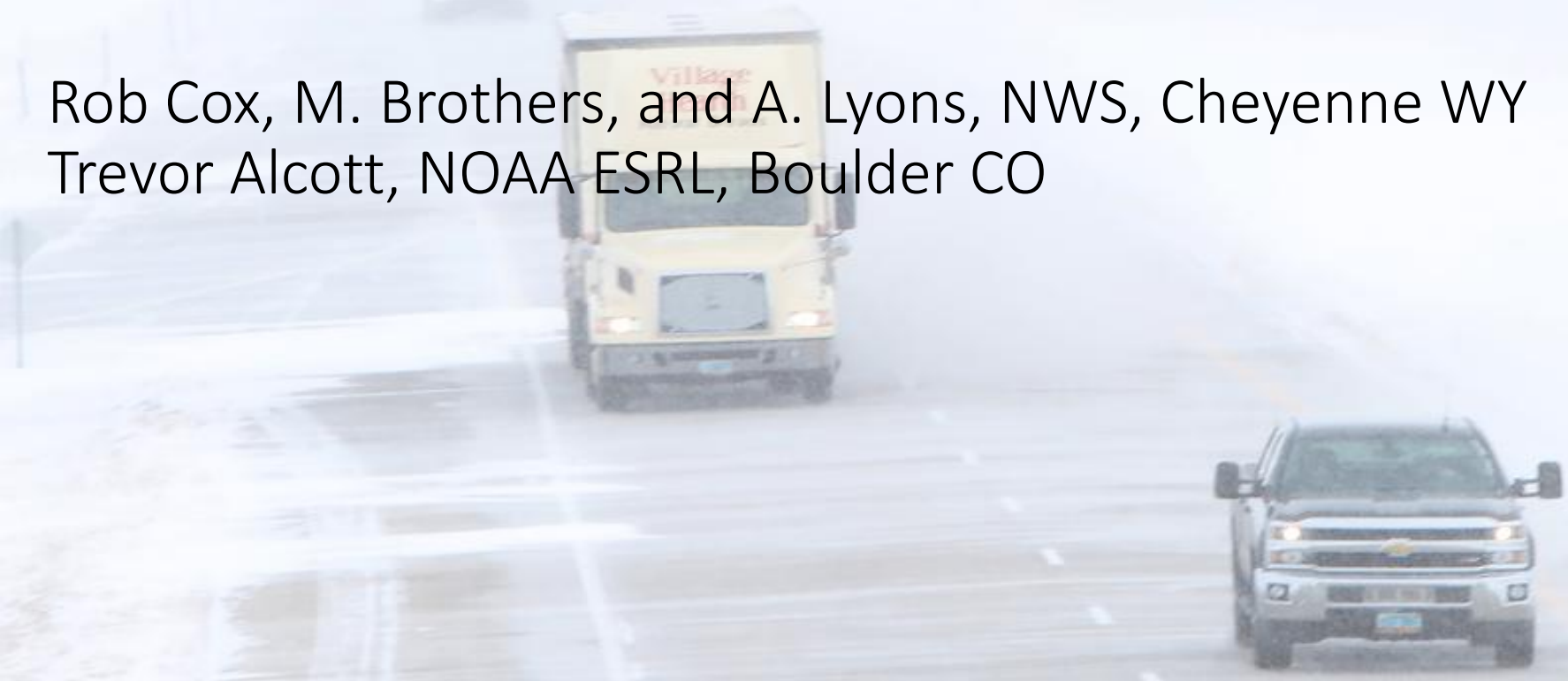
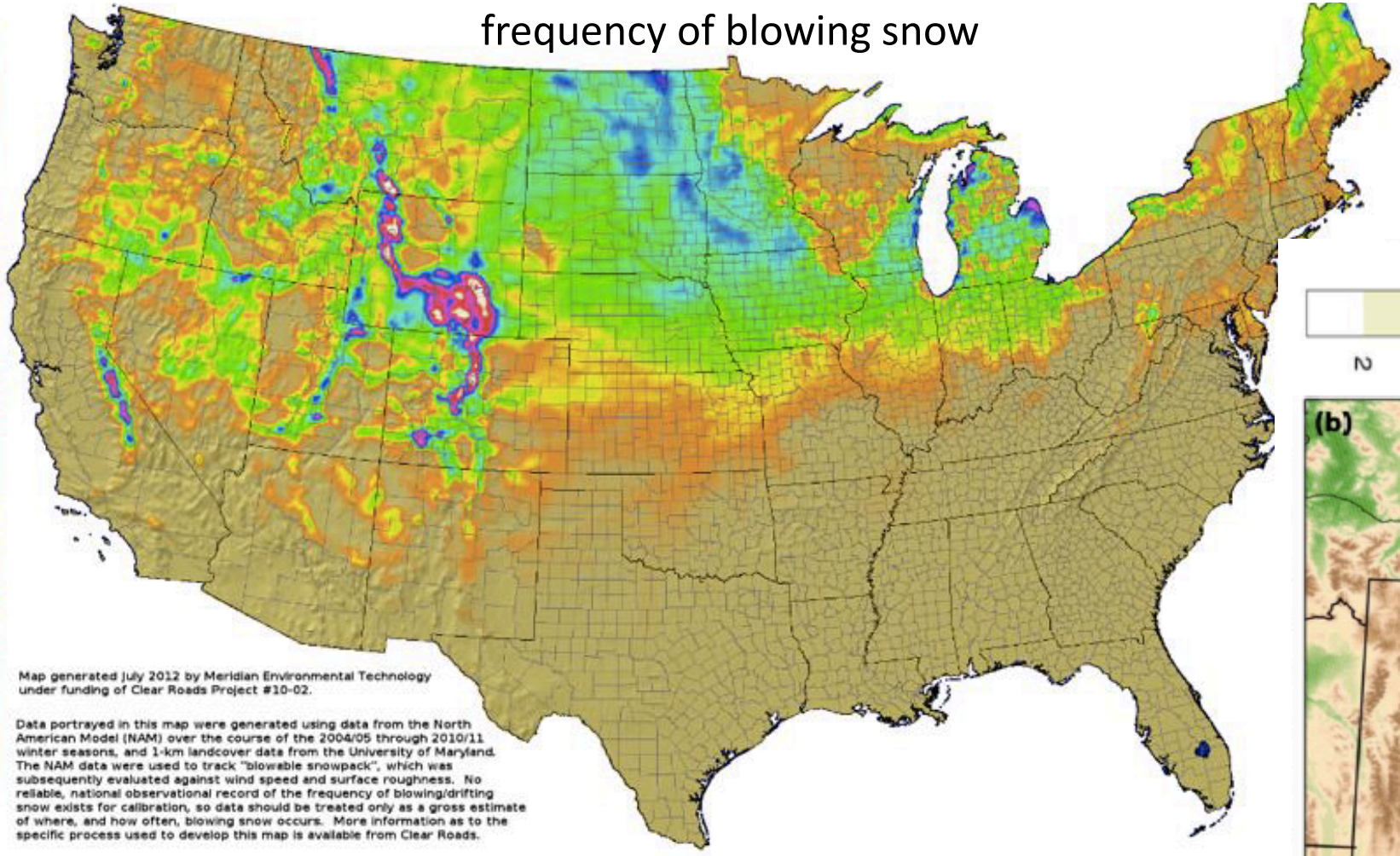
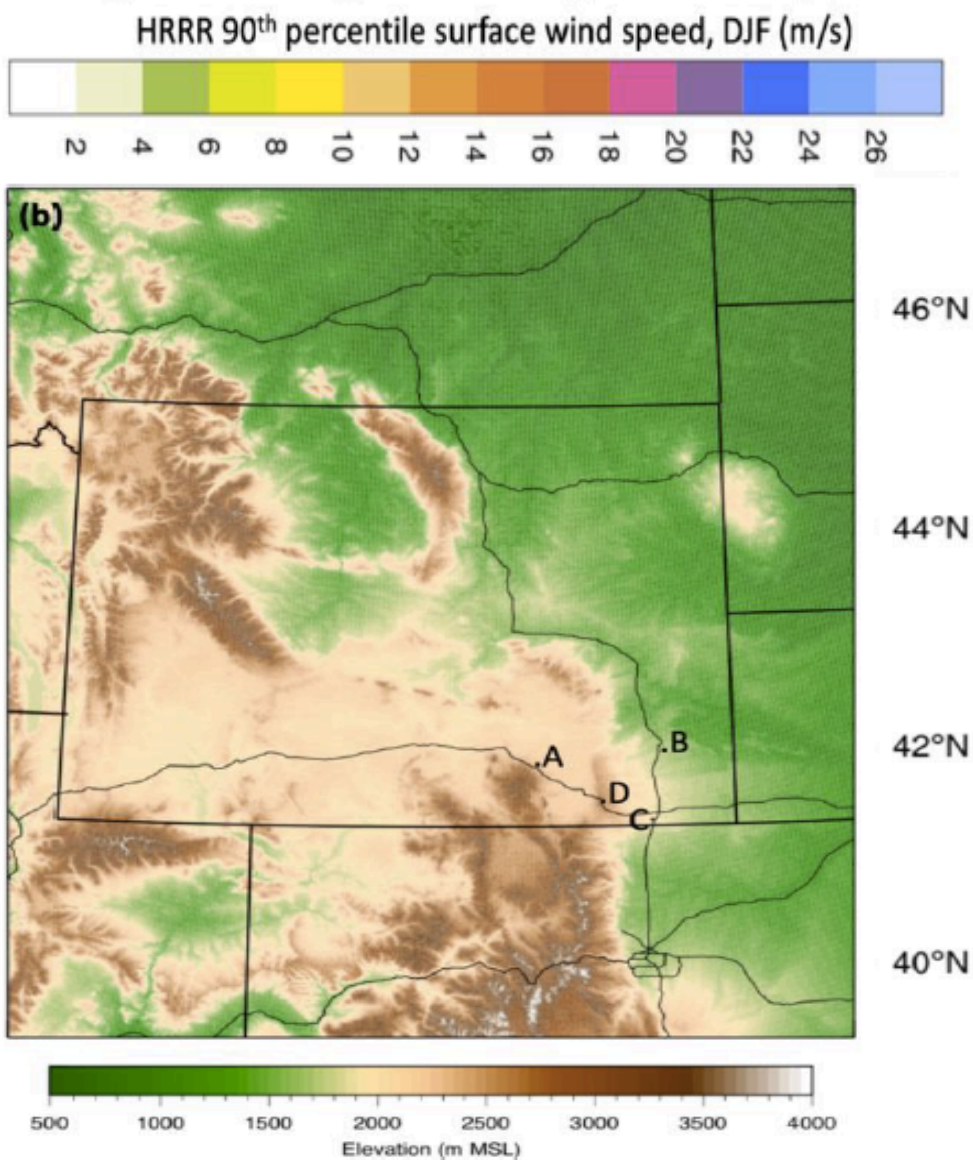


funded by NOAA CSTAR grant NA19NWS4680005

Paper 10A.2 at the 10th Conference on Transition from Research to Operations, AMS Annual Meeting, Boston, 15 Jan 2020



Motivation



Each year Wyoming roads experience …

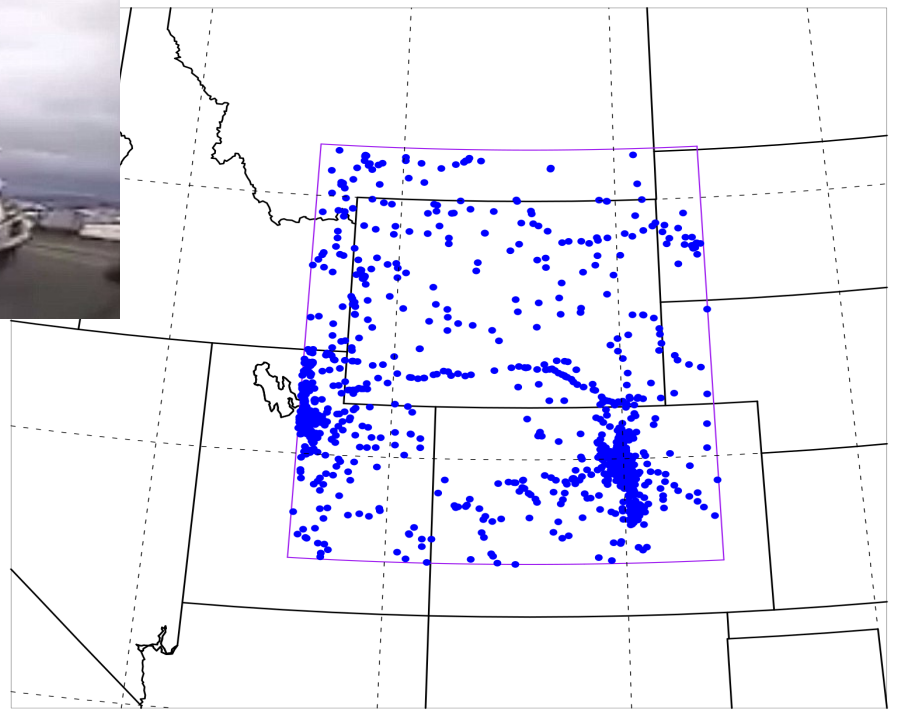
- ~ 17 weather-related road closures, averaging ~8 hours each, costing ~$14M each in business losses
- ~ 50 truck blow-overs

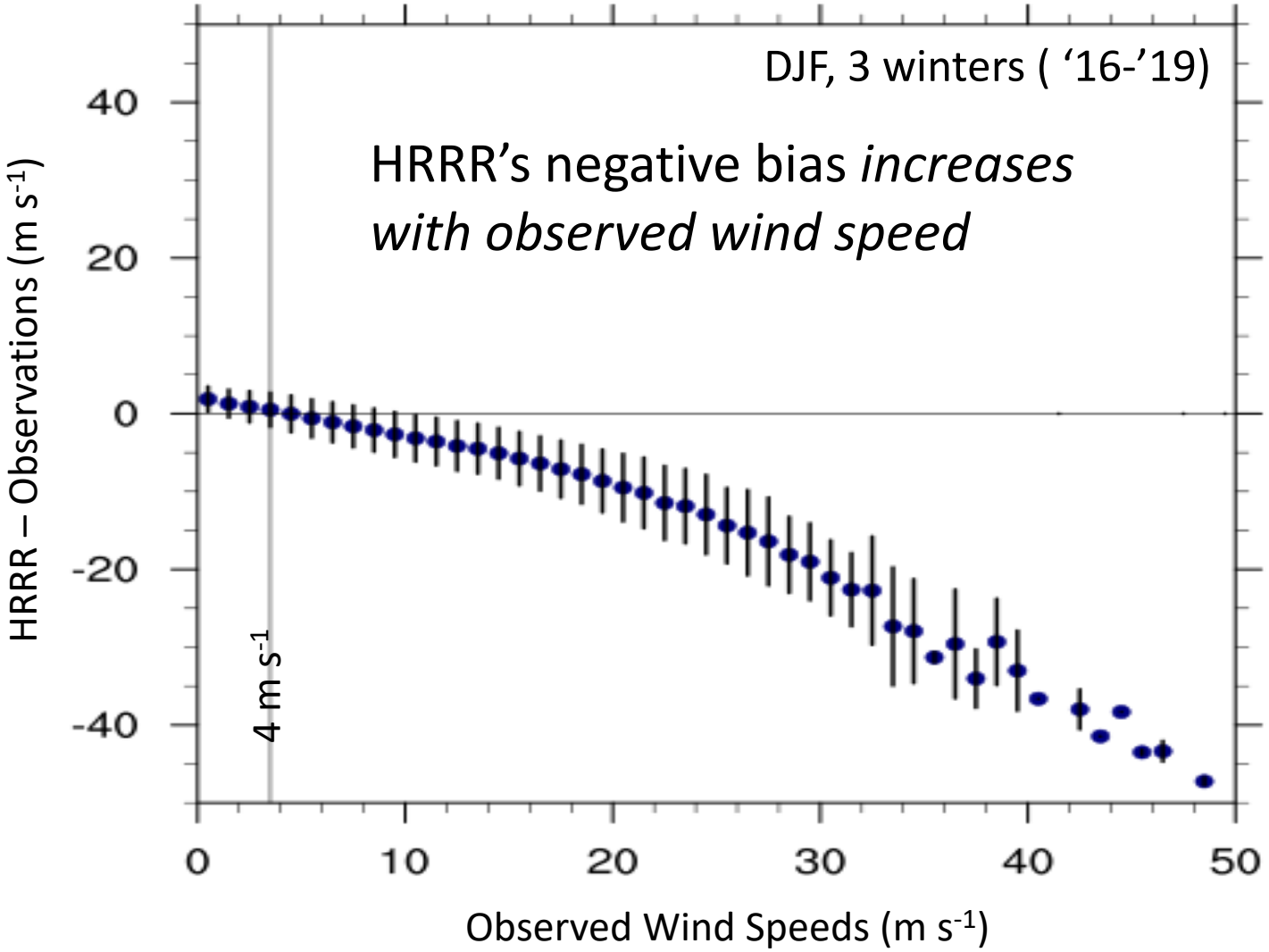
CSTAR goal: Improved operational prediction of blowing and falling snow and extreme winds in winter storms

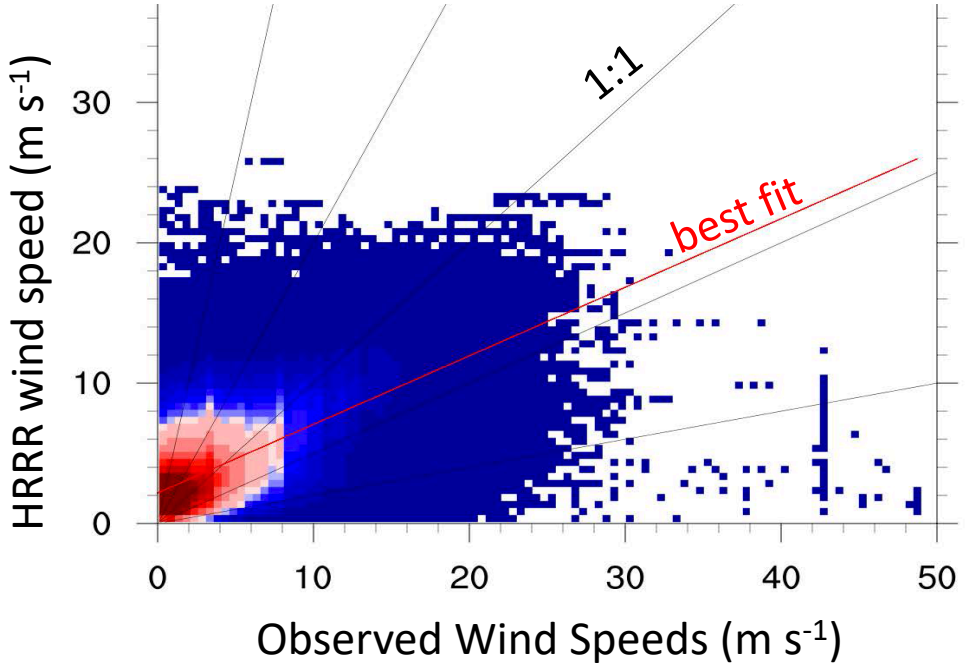
1. **HRRR validation:**
   a. **extreme winds**
   b. **snow squall conditions**
2. **Use spatially resolved real-time HRRR output to map out several *applied products:***
   a. **extreme crosswinds along highways and airport runways**
   b. **blowing & drifting snow**
   c. **snow squalls**
3. **HRRR validation of these applied products**
   a. **Dept of Transportation weather sensors**
   b. **web cam imagery (machine learning)**
4. **Examine the benefit of higher-resolution (1.0 km) convection-permitting HRRR-like WRF simulations.**

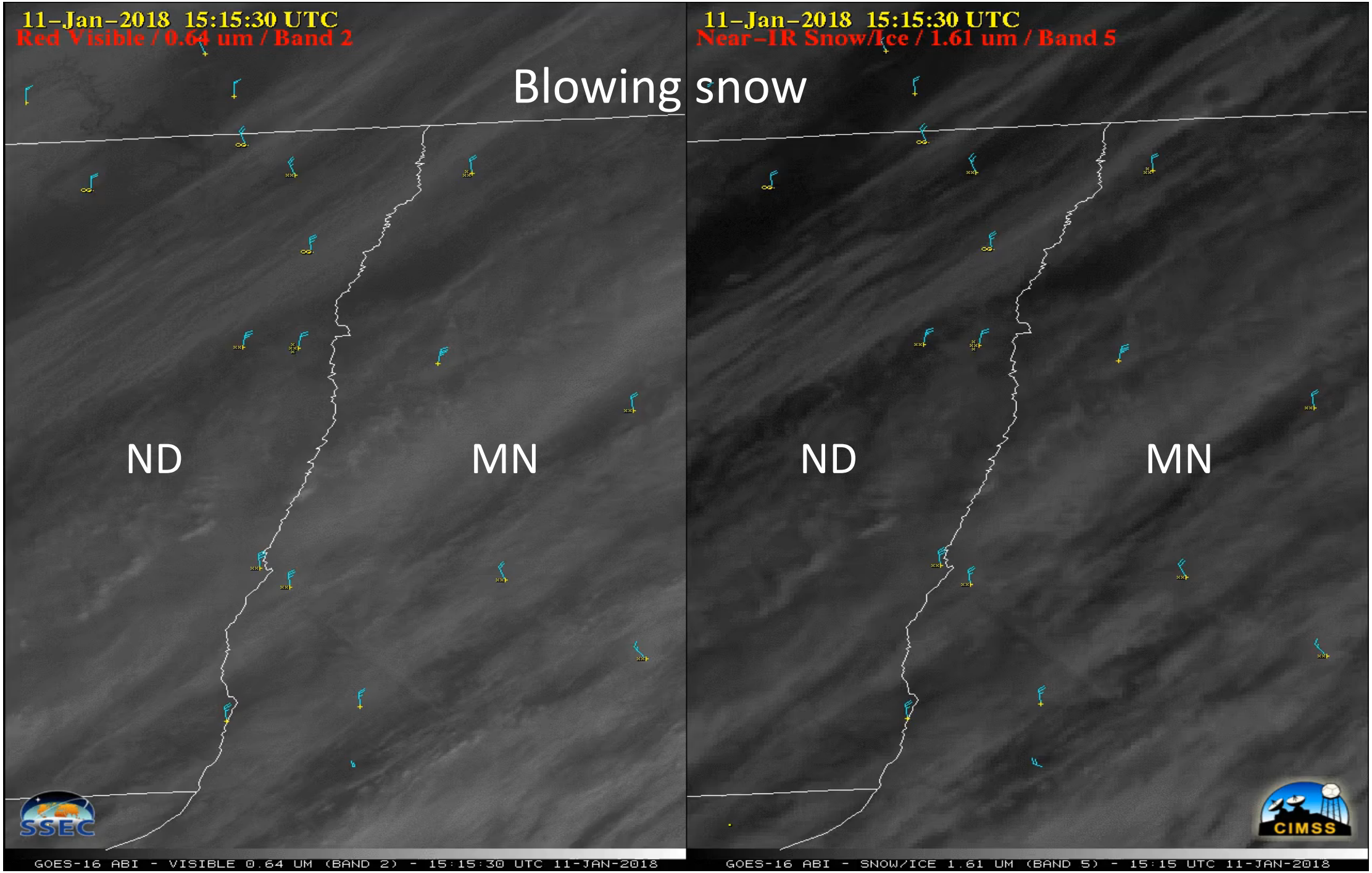
Wind Speed Validation

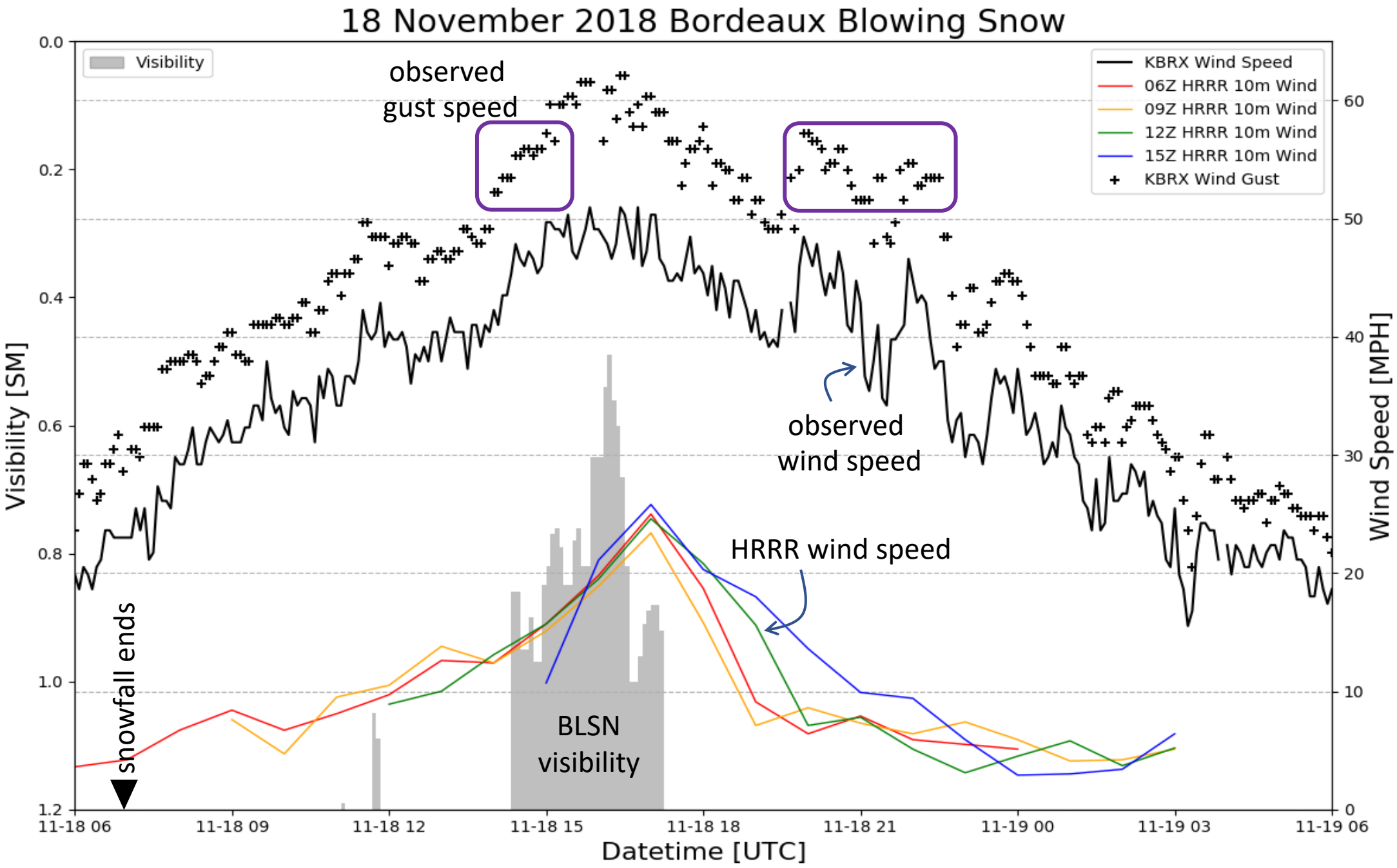
Collins et al., R2O talk this morning








11-Jan-2018 15:15:30 UTC
Red Visible / 0.64 um / Band 2
Blowing snow
ND
MN
SSEC
GOES-16 ABI - VISIBLE 0.64 UM (BAND 2) - 15:15:30 UTC 11-JAN-2018
11-Jan-2018 15:15:30 UTC
Near-IR Snow/Ice / 1.61 um / Band 5
ND
MN
CIMSS
GOES-16 ABI - SNOW/ICE 1.61 UM (BAND 5) - 15:15 UTC 11-JAN-2018



see poster #1480 by Matthew Brothers et al. today at 4 pm

Blowing Snow & visibility: towards empirical HRRR based BLSN forecasts

- Follow the NWS ForecastBuilder to predict 4 types of BLSN:
  - Patchy BLSN 10% visibility below 3 SM
  - Areas of BLSN 30% visibility below 1 SM
  - Definite BLSN 60% visibility below ½ SM
  - BLSN Blizzard 80% visibility below ½ SM

  This classification combines probability with intensity. It is very qualitative, but the underlying model-derived parameter is quantitative (CRED)

- Key parameters from HRRR are:
  - surface wind speed (10 m)
  - surface temperature (2 m)
  - snow depth
  - snow age
  - max sfc temperature encountered by the top snow layer

  These 2 parameters are not available in instantaneous model output (25 hr history needed)

- Plan is to adapt the NWS ForecastBuilder code to HRRR model output
  - Focus is on High Plains / Rockies, but this BLSN parameter can be plotted where-ever HRRR data are available.

Blowing Snow & visibility: towards empirical HRRR based BLSN forecasts

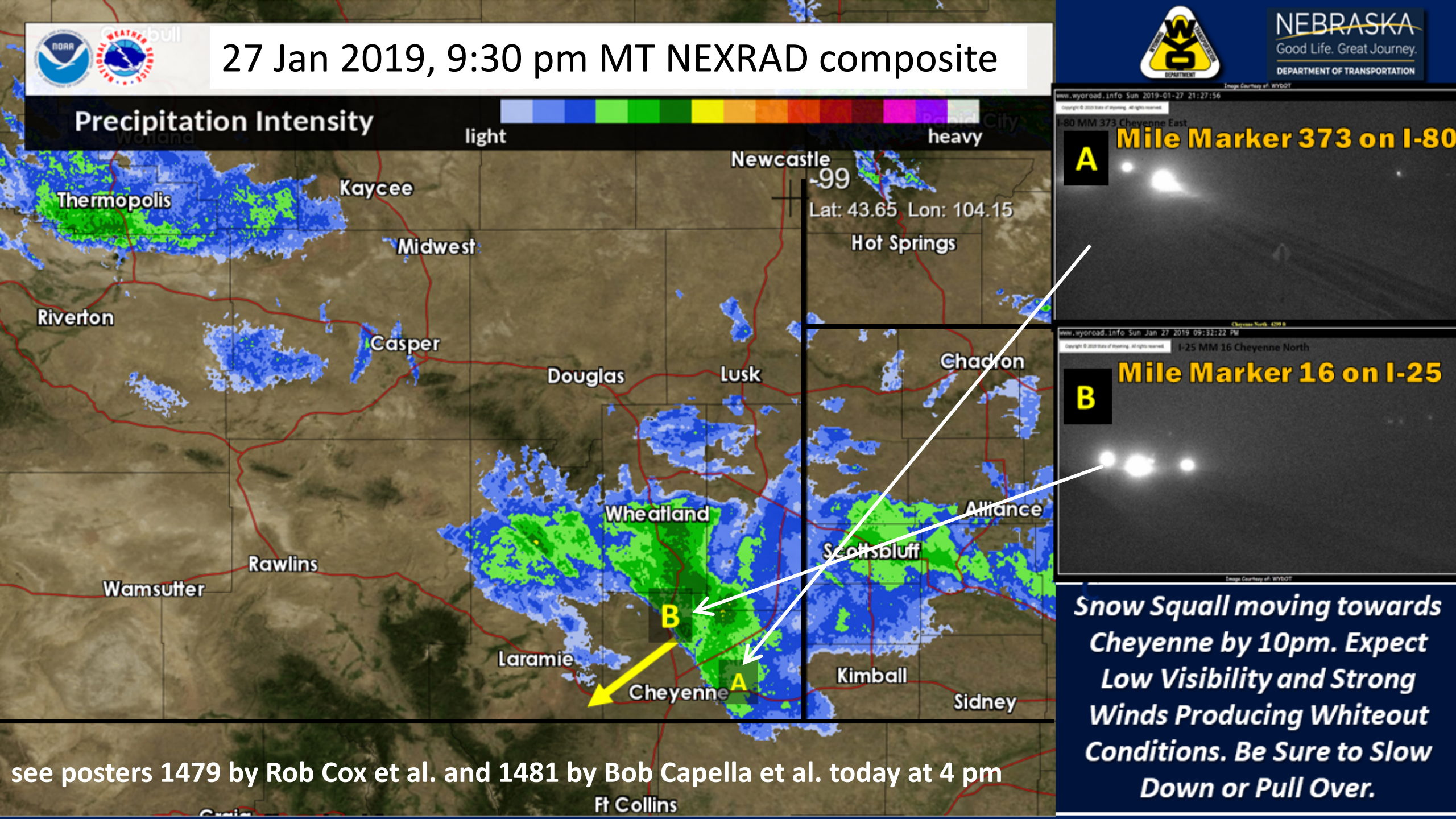
This BLSN guidance has never been validated.

Validation efforts:

- ASOS visibility (following Baggaley and Hanesiak 2005)
- Mesowest visibility
- Archived roadsite webcam imagery:
  - using image pattern recognition, machine learning
  - for the same 4 BLSN categories, plus drifting snow as a 5th one.
- GOES-R satellite image validation of BLSN ??
- This validation may lead to **modifications to the algorithm:**
  - include wind gusts or TKE?
  - add a site-specific wind direction function

Snow Squalls – Definition

1. Snow squalls are convective systems that produce gusty winds and heavy snow, resulting into sudden near-zero visibility.
2. Falling temperatures can produce a “flash freeze” road surfaces.
3. Difficult to predict …
4. Difficult to detect …
   - May be shallow, therefore may be missed by the NEXRAD network


27 Jan 2019, 9:30 pm MT NEXRAD composite
Precipitation Intensity
light
heavy
Newcastle
-99
Lat: 43.65 Lon: 104.15
Hot Springs
Thermopolis
Kaycee
Midwest
Riverton
Casper
Douglas
Lusk
Chadron
Wheatland
Alliance
Scottsbluff
Rawlins
Wamsutter
Laramie
Cheyenne
Kimball
Sidney
Ft Collins
A
B
NEBRASKA
Good Life. Great Journey.
DEPARTMENT OF TRANSPORTATION
I-80 MM 373 Cheyenne East
Mile Marker 373 on I-80
I-25 MM 16 Cheyenne North
Mile Marker 16 on I-25
Snow Squall moving towards Cheyenne by 10pm. Expect Low Visibility and Strong Winds Producing Whiteout Conditions. Be Sure to Slow Down or Pull Over.
see posters 1479 by Rob Cox et al. and 1481 by Bob Capella et al. today at 4 pm

Snow Squall parameter

an environmental parameter that correlates well with the likelihood & intensity of SNSQs

– at least in New England (Banacos et al., 2014)

$$\mathrm{SNSQ} = \left(\frac{\overline{RH}_{sfc-2km} - 60\%}{15\%}\right) * \left(\frac{4K - (\theta_e|_{2km} - \theta_e|_{sfc})}{4K}\right) * \left(\frac{\left\|\vec{V}\right\|_{sfc-2km}}{9ms^{-1}}\right)$$

Parameter Calibrated to 1.0

0-2 km Mean Relative Humidity (Set to 0 if negative)

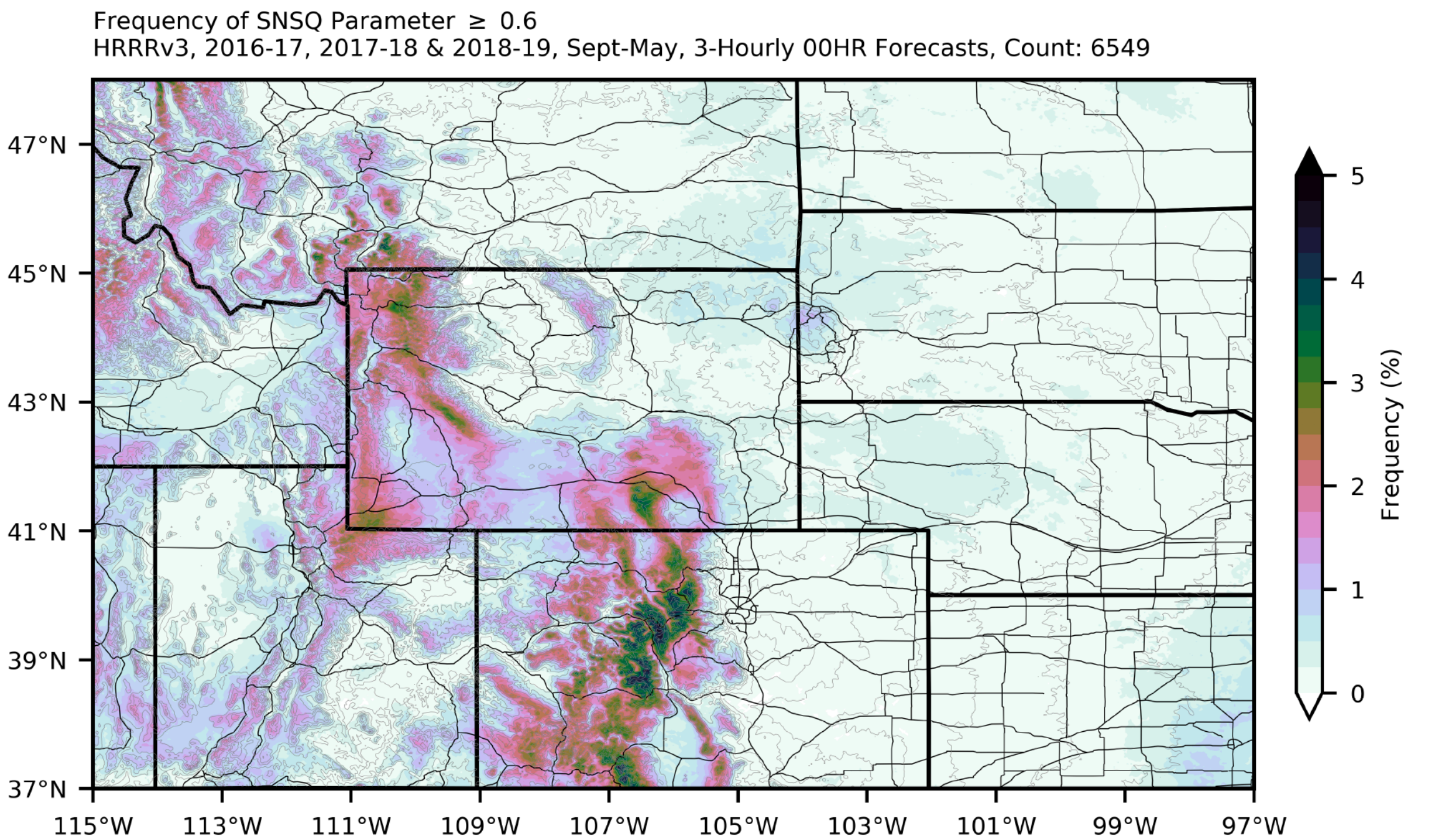
0-2 km Instability (Set to 0 if negative)

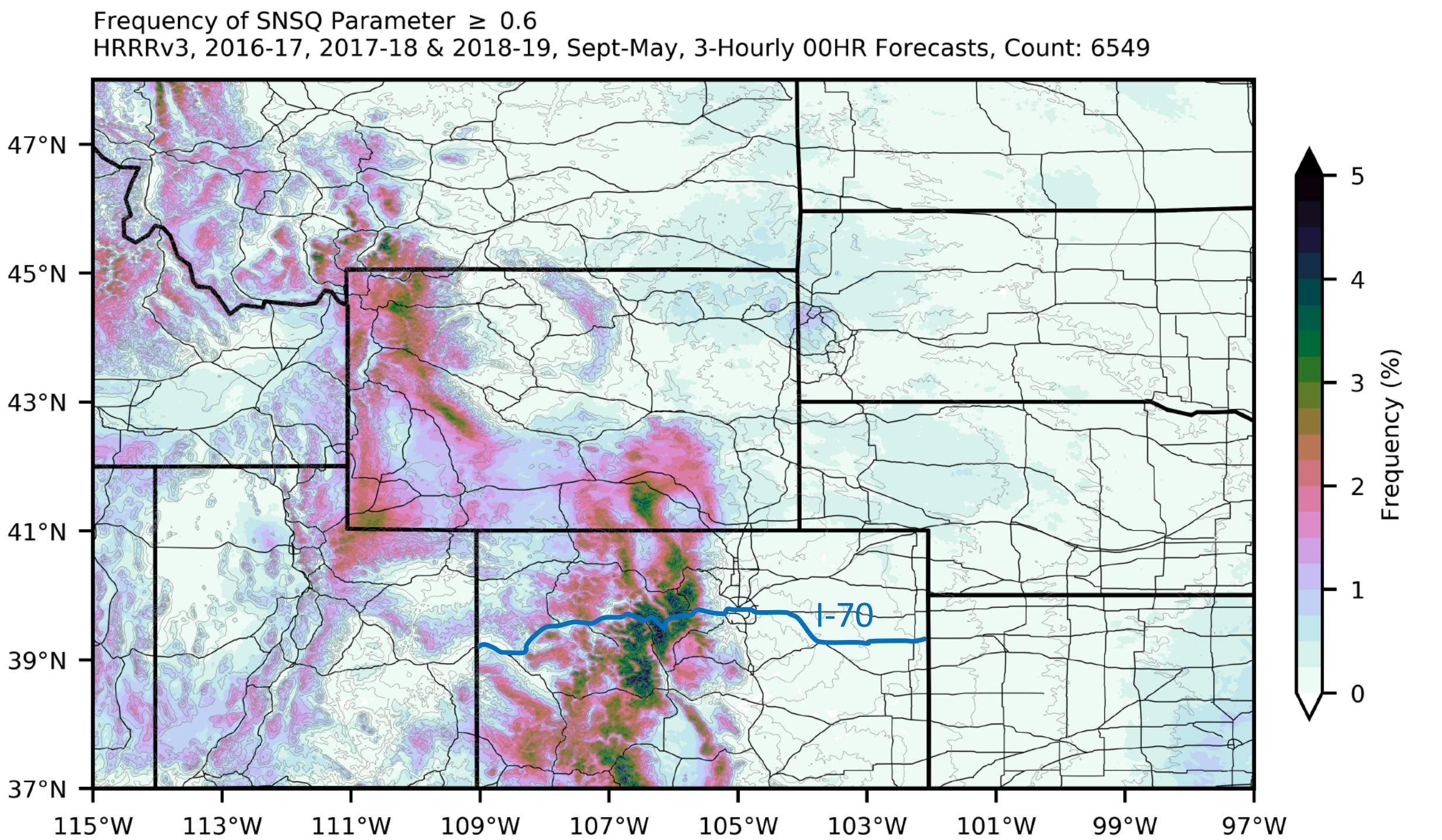
0-2 km Mean Wind Speed

plus, $T_w < 0°C$

December 18th 2019

https://twitter.com/LeeGoldbergABC7/status/1207424106624438272


Frequency of SNSQ Parameter ≥ 0.6
HRRRv3, 2016-17, 2017-18 & 2018-19, Sept-May, 3-Hourly 00HR Forecasts, Count: 6549
47°N
45°N
43°N
41°N
39°N
37°N
115°W
113°W
111°W
109°W
107°W
105°W
103°W
101°W
99°W
97°W
5
4
3
2
1
0
Frequency (%)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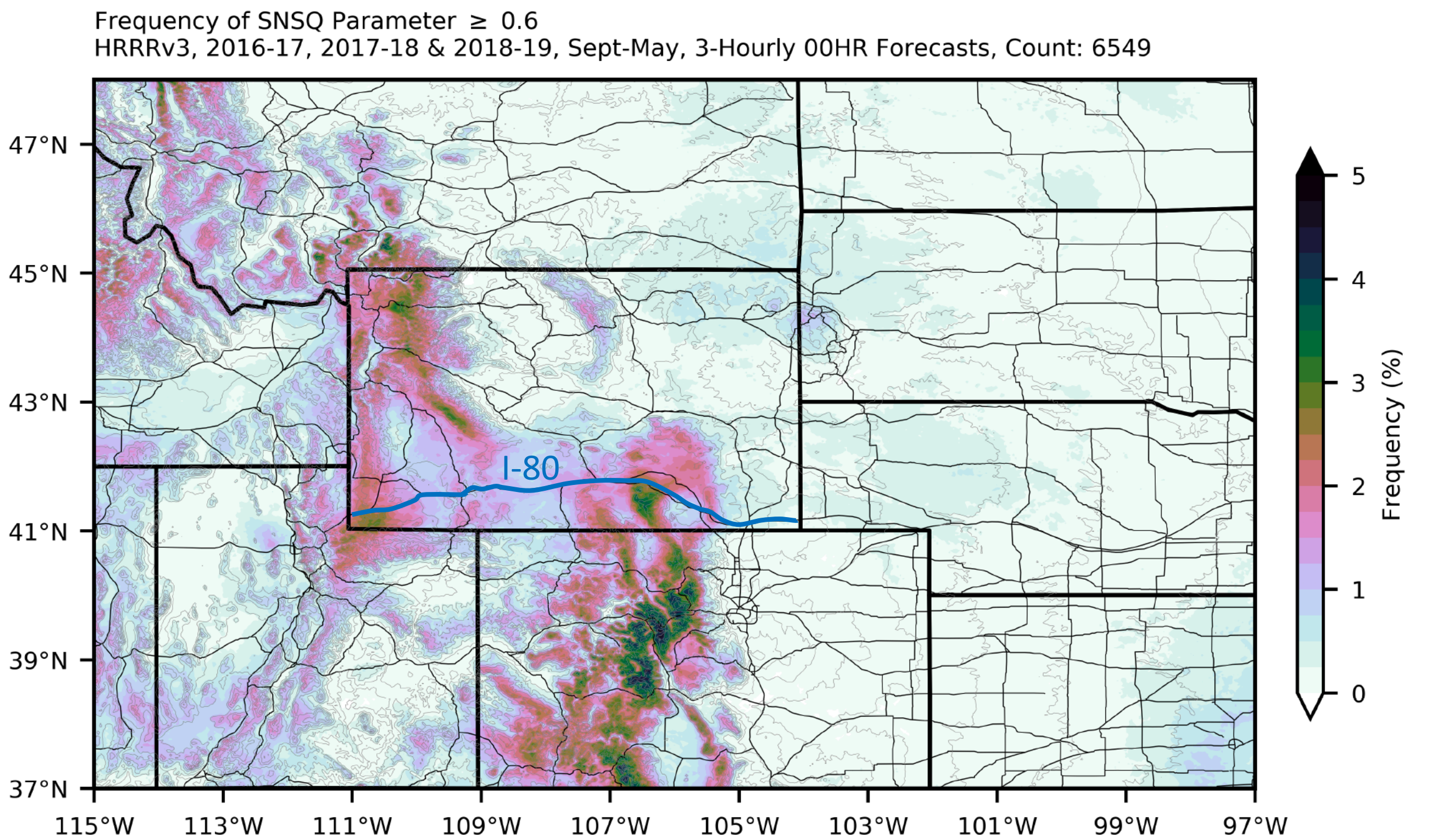
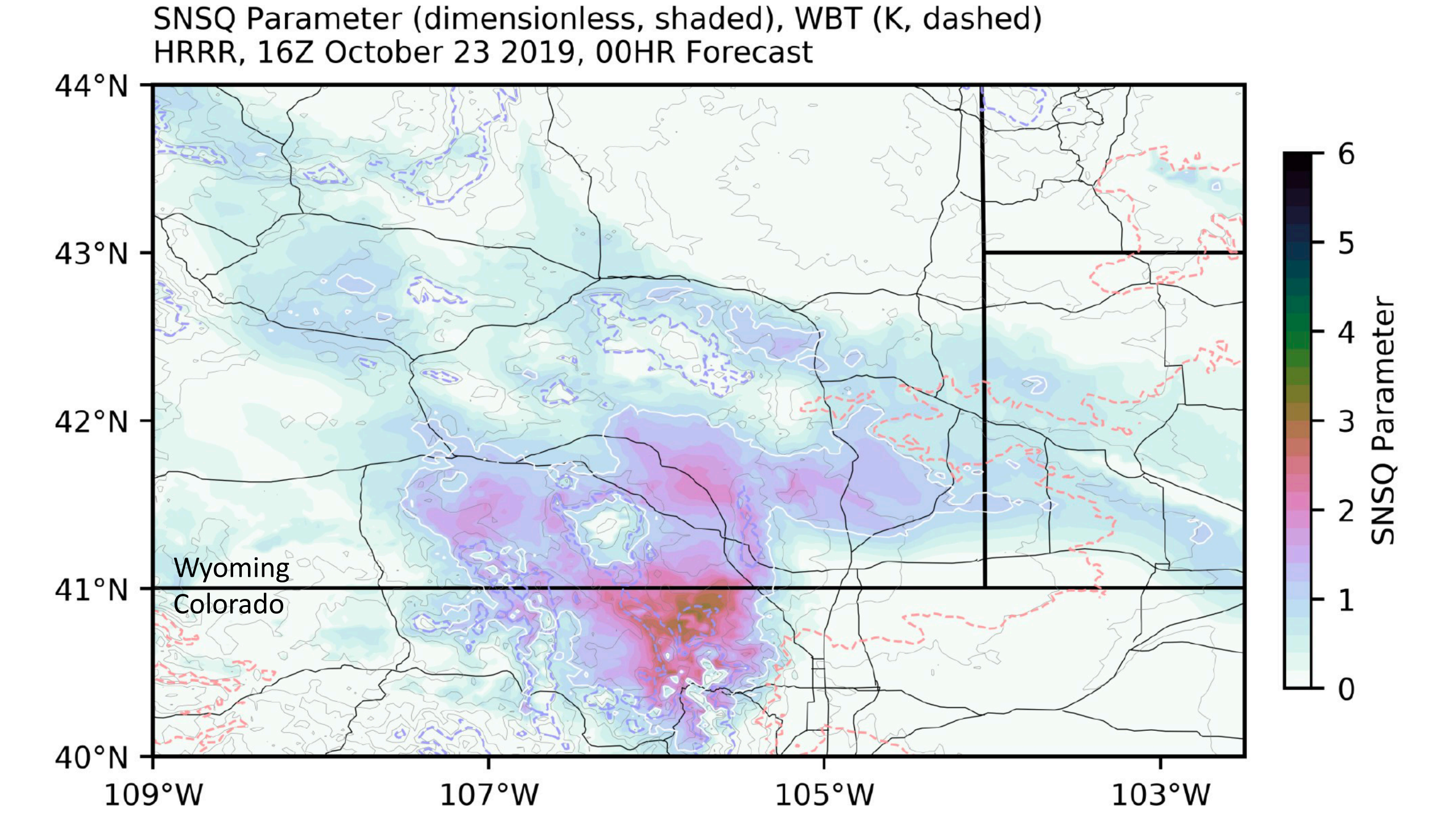
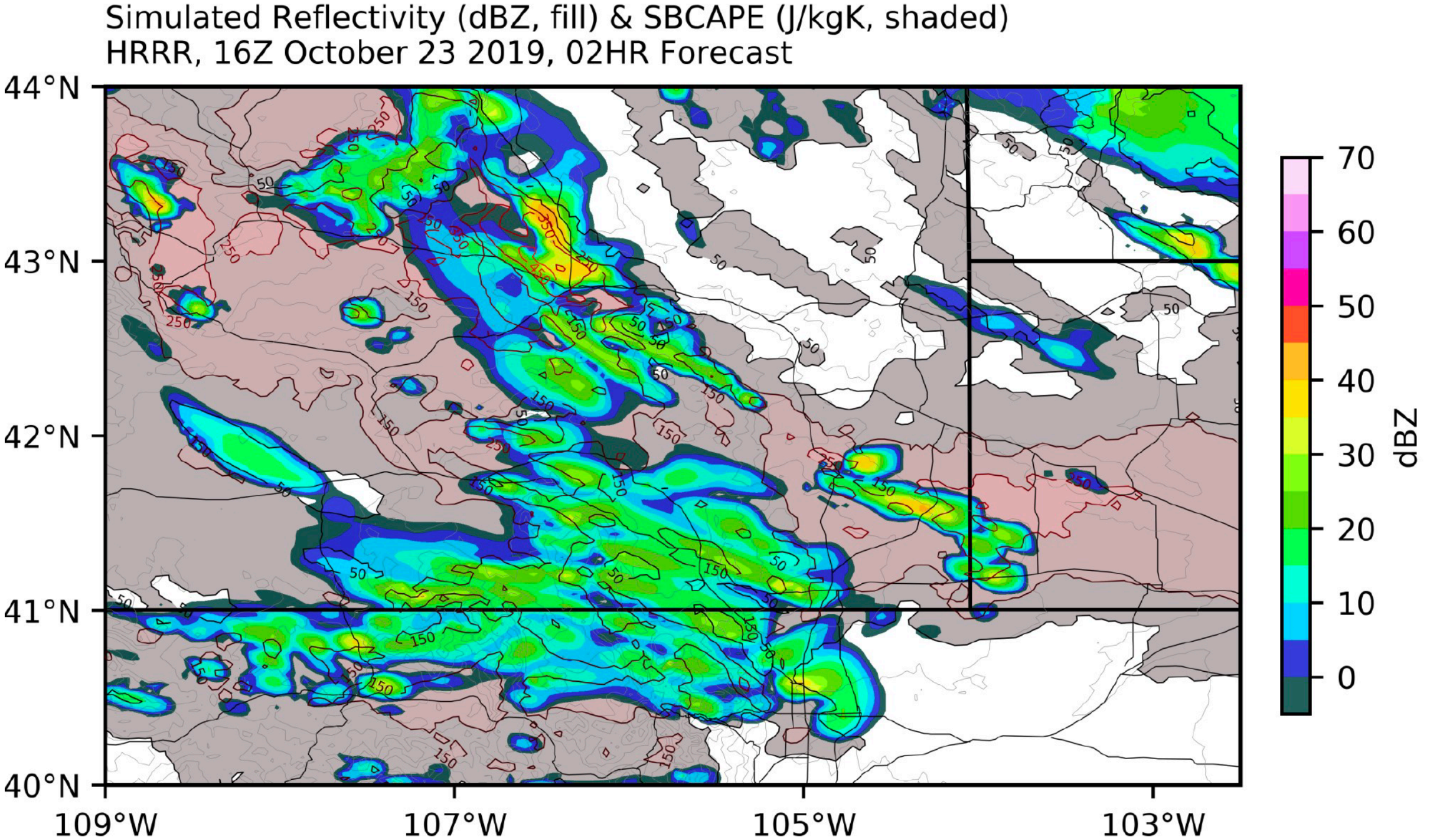
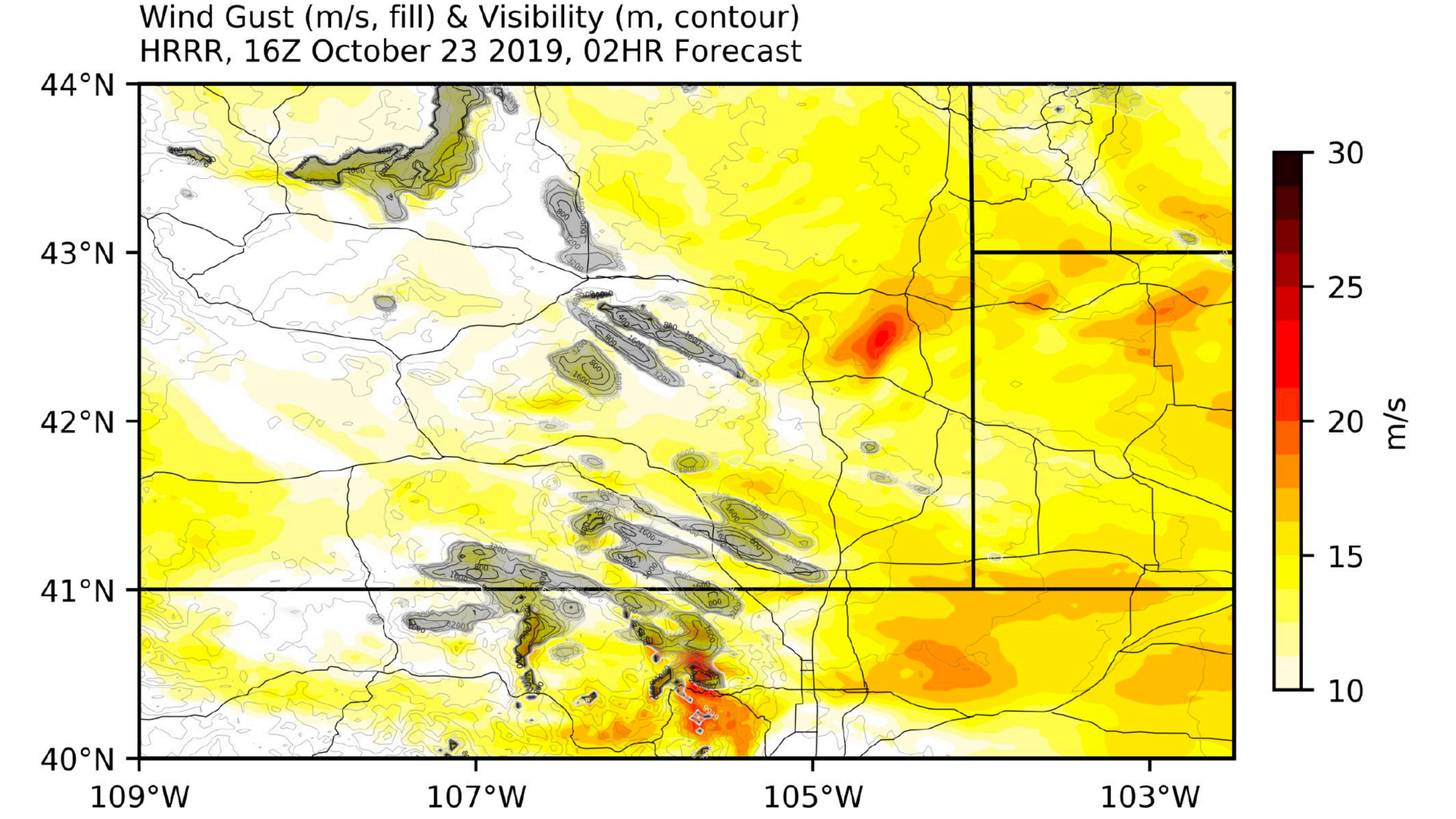
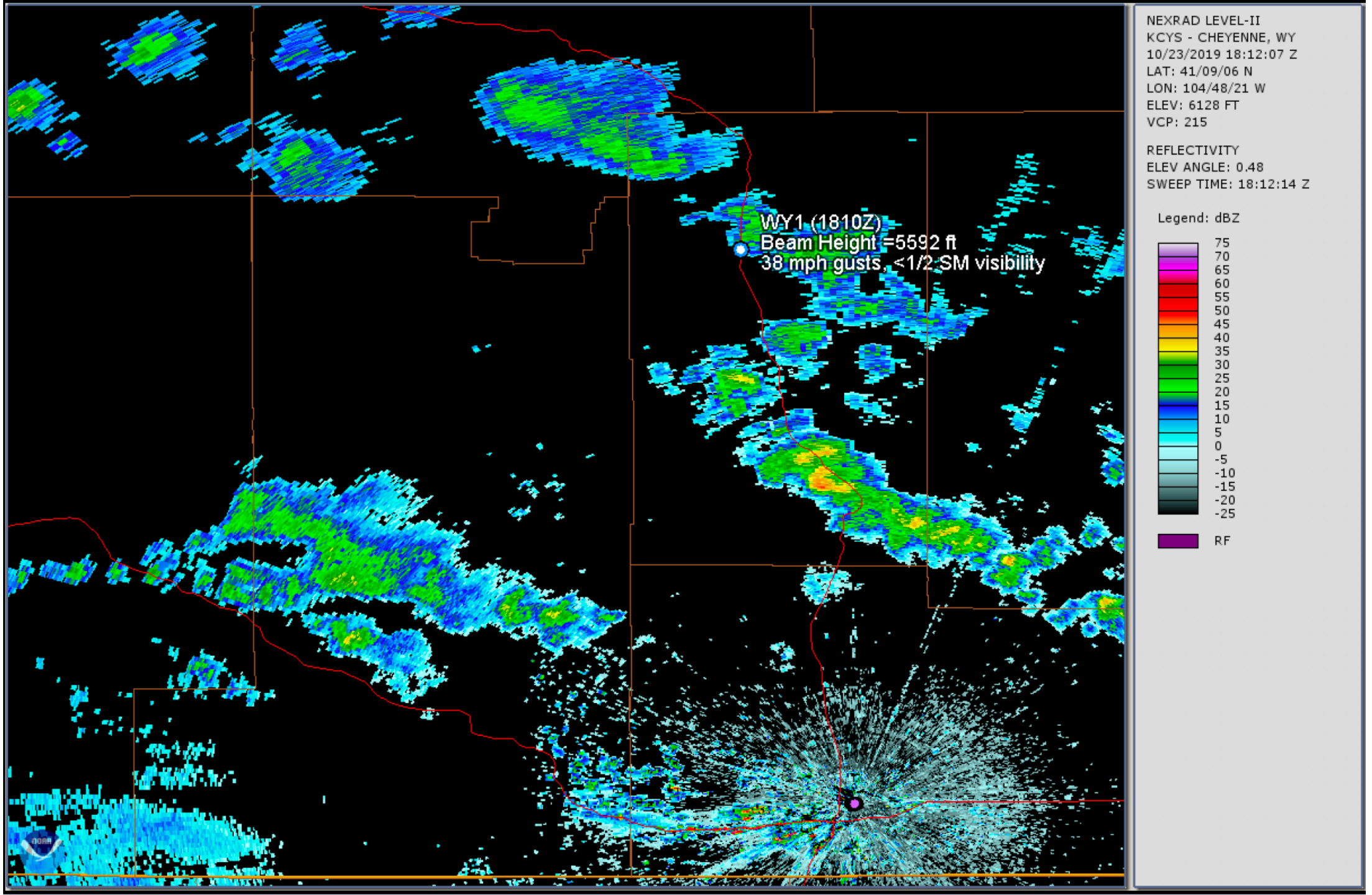
HRRRv3, 2016-17, 2017-18 & 2018-19, Sept-May, 3-Hourly 00HR Forecasts, Count: 6549
47°N
45°N
43°N
41°N
39°N
37°N
115°W
113°W
111°W
109°W
107°W
105°W
103°W
101°W
99°W
97°W
I-70
5
4
3
2
1
0
Frequency (%)

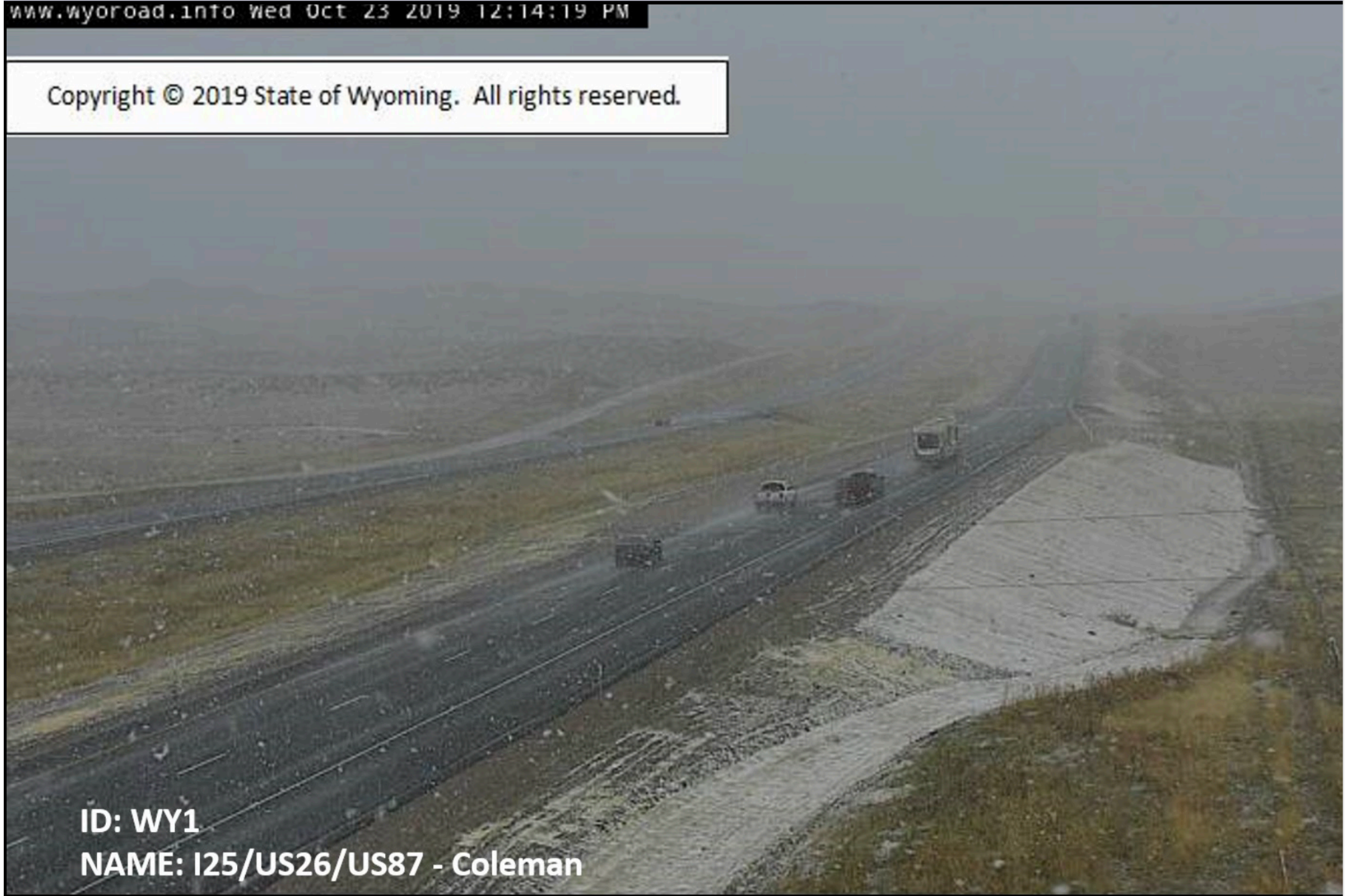

Frequency of SNSQ Parameter ≥ 0.6
HRRRv3, 2016-17, 2017-18 & 2018-19, Sept-May, 3-Hourly 00HR Forecasts, Count: 6549
47°N
45°N
43°N
41°N
39°N
37°N
115°W
113°W
111°W
109°W
107°W
105°W
103°W
101°W
99°W
97°W
I-80
5
4
3
2
1
0
Frequency (%)


SNSQ Parameter (dimensionless, shaded), WBT (K, dashed)
HRRR, 16Z October 23 2019, 00HR Forecast
44°N
43°N
42°N
41°N
40°N
109°W
107°W
105°W
103°W
Wyoming
Colorado
SNSQ Parameter
0
1
2
3
4
5
6


Simulated Reflectivity (dBZ, fill) & SBCAPE (J/kgK, shaded)
HRRR, 16Z October 23 2019, 02HR Forecast
44°N
43°N
42°N
41°N
40°N
109°W
107°W
105°W
103°W
dBZ
70
60
50
40
30
20
10
0

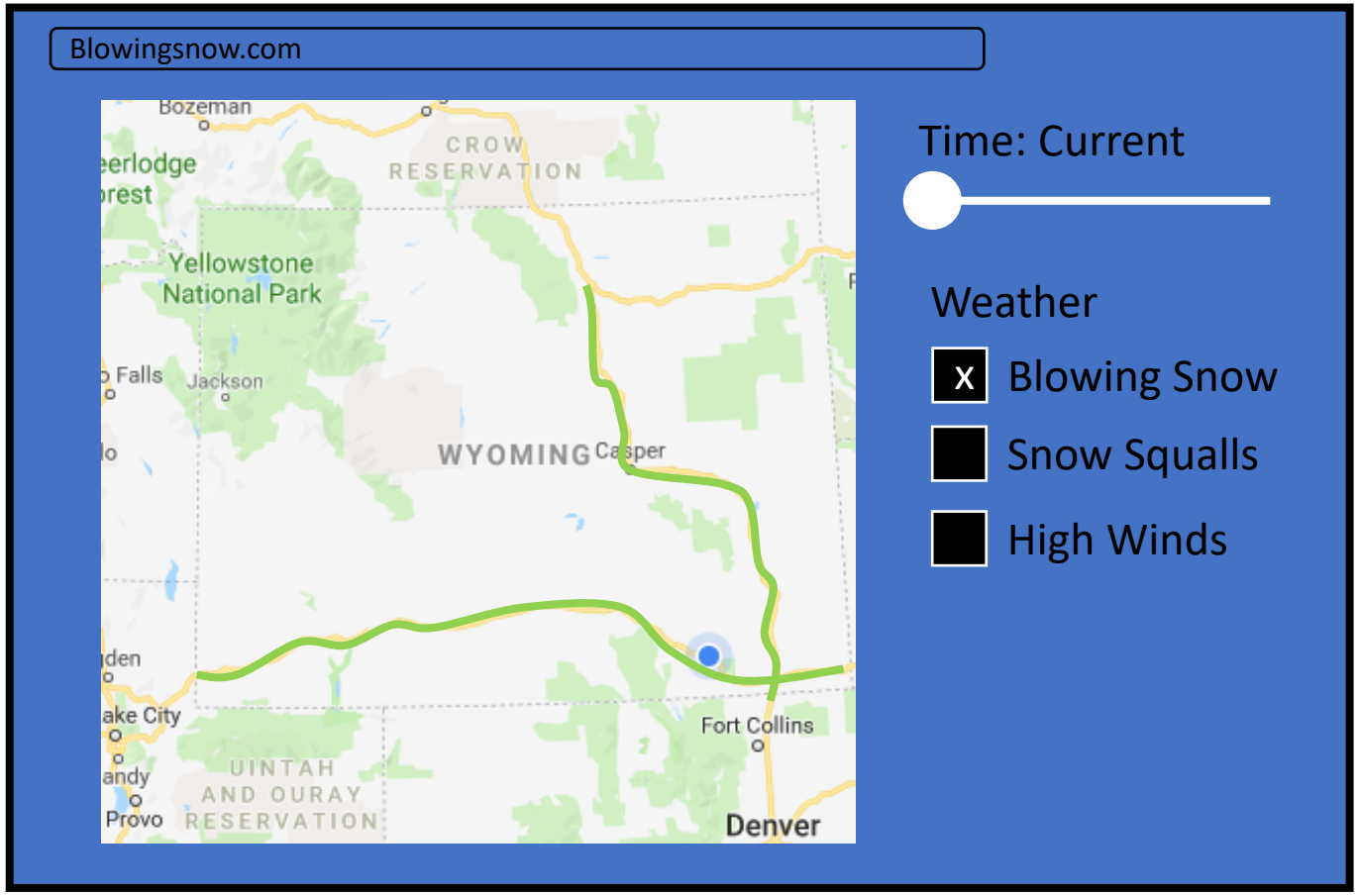

Wind Gust (m/s, fill) & Visibility (m, contour)
HRRR, 16Z October 23 2019, 02HR Forecast
44°N
43°N
42°N
41°N
40°N
109°W
107°W
105°W
103°W
30
25
20
15
10
m/s


WY1 (1810Z)
Beam Height =5592 ft
38 mph gusts , <1/2 SM visibility
NEXRAD LEVEL-II
KCYS - CHEYENNE, WY
10/23/2019 18:12:07 Z
LAT: 41/09/06 N
LON: 104/48/21 W
ELEV: 6128 FT
VCP: 215
REFLECTIVITY
ELEV ANGLE: 0.48
SWEEP TIME: 18:12:14 Z
Legend: dBZ
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
RF


www.wyoroad.info Wed Oct 23 2019 12:14:19 PM
Copyright © 2019 State of Wyoming. All rights reserved.
ID: WY1
NAME: I25/US26/US87 - Coleman

Real-time predictions

Goal: develop a zoomable Google maps-based web portal to disseminate hazardous winter weather along interstates and highways.



Real-time predictions

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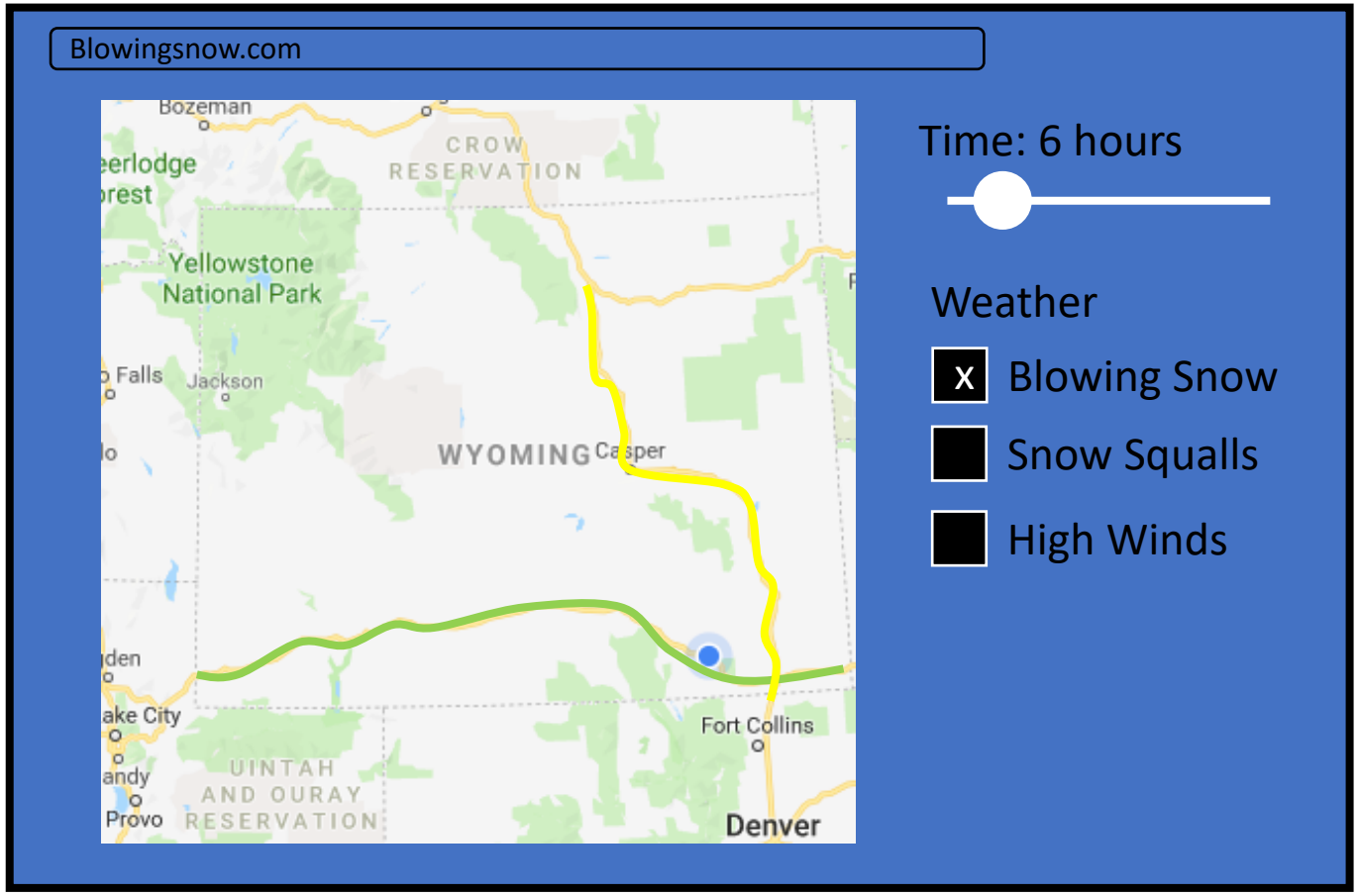

Real-time predictions

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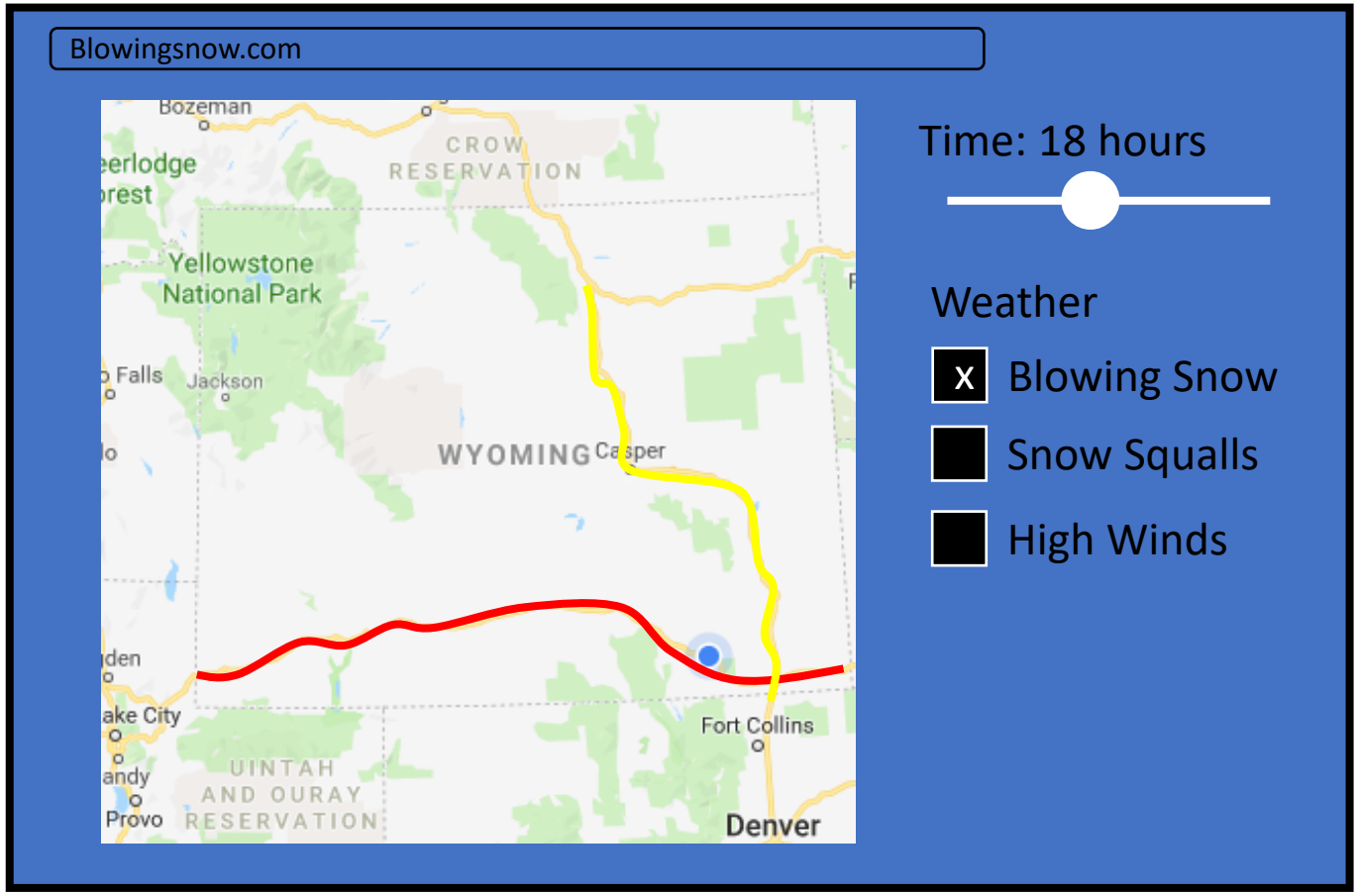

Conclusions

- Hazardous winter road weather can be predicted better.
- HRRR serves as a great start.

BLSN Observation Techniques

- **Automatic**

- At higher wind speeds (10 knots or greater), the upward vertical velocity of the snow particles usually is sufficient to be incorrectly interpreted as rain.

- Change is made by evaluating sky condition and 15-minute average data for ambient temperature and wind.

- ASOS evaluates all LEDWI [Light Emitting Diode Weather Identifier (10ft)] reports of rain with an ambient temperature of 32 o F or less. Under these conditions, either blowing snow (BLSN) or unknown precipitation (UP), is reported

- **When all data are available, ASOS reports blowing snow when:**
  - **Visibility is less than 7 statute miles**
  - **Ambient temperature is 14 o F or less**
  - **Sky cover is less than overcast or the cig height is greater than 10kft**
  - **Wind speed is greater than 22 knots**

- If these conditions are not met, ASOS reports UP

ASOS Users Guide, FMH-1

- **Manual**

- **12.6.8 Present Weather Group (w'w').** The standards for observing and reporting present weather are described in Chapter 8.
  - **b) Descriptor Qualifier.** Only one descriptor shall be coded for each weather phenomena group, e.g., "-FZDZ". Mist (BR) shall not be coded with any descriptor.
    - **2.** The descriptors low drifting (DR) and blowing (BL) shall only be coded with dust (DU),sand (SA), and snow (SN), e.g., "BLSN" or "DRSN". DR shall be coded for DU, SA, or SN raised by the wind to less than six feet above the ground. When blowing snow is observed with snow falling from clouds, both phenomena are reported, e.g., "SN BLSN". If there is blowing snow and the observer cannot determine whether or not snow is also falling, then BLSN shall be reported.

Table 12-2. Notations for Reporting Present Weather[1]

QUALIFIER		WEATHER PHENOMENA		
INTENSITY[2] OR PROXIMITY 1	DESCRIPTOR 2	PRECIPITATION 3	OBSCURATION 4	OTHER 5
- Light Moderate[3] + Heavy **VC** In the Vicinity[4]	**MI** Shallow **PR** Partial **BC** Patches **DR** Low Drifting **BL** Blowing **SH** Shower(s) **TS** Thunderstorm **FZ** Freezing	**DZ** Drizzle **RA** Rain **SN** Snow **SG** Snow Grains **IC** Ice Crystals **PL** Ice Pellets **GR** Hail **GS** Snow Pellets **UP** Unknown Precipitation	**BR** Mist **FG** Fog **FU** Smoke **VA** Volcanic Ash **DU** Widespread Dust **SA** Sand **HZ** Haze **PY** Spray	**PO** Well-Developed Dust/Sand Whirls **SQ** Squalls **FC** Funnel Cloud Tornado Waterspout[5] **SS** Sandstorm **DS** Duststorm

Issuance Criteria for Snow Squall Warnings (SQW)

- WFOs should issue SQWs when there is radar or satellite indication and/or reliable reports (e.g., from DOTs, webcams, road network observations etc.) of snow squalls meeting or exceeding one or more of the following conditions:
  - **Condition 1: Visibility 1/4SM or less in snow with sub-freezing ambient road temperatures**
  - **Condition 2: Plunging temperatures behind an arctic front sufficient to produce flash freezes, along with a significant reduction in visibility from falling and/or blowing snow.**
- Forecaster judgment regarding impacts including time of day, day of week, and other societal factors should be considered. In those instances when lesser impacts are expected, a Special Weather Statement (SPS) can be issued.