Observations on the Marshall Fire

A Survivor's Perspective

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NCAR Research Applications Laboratory

17 February 2022

NCAR | RESEARCH APPLICATIONS LABORATORY

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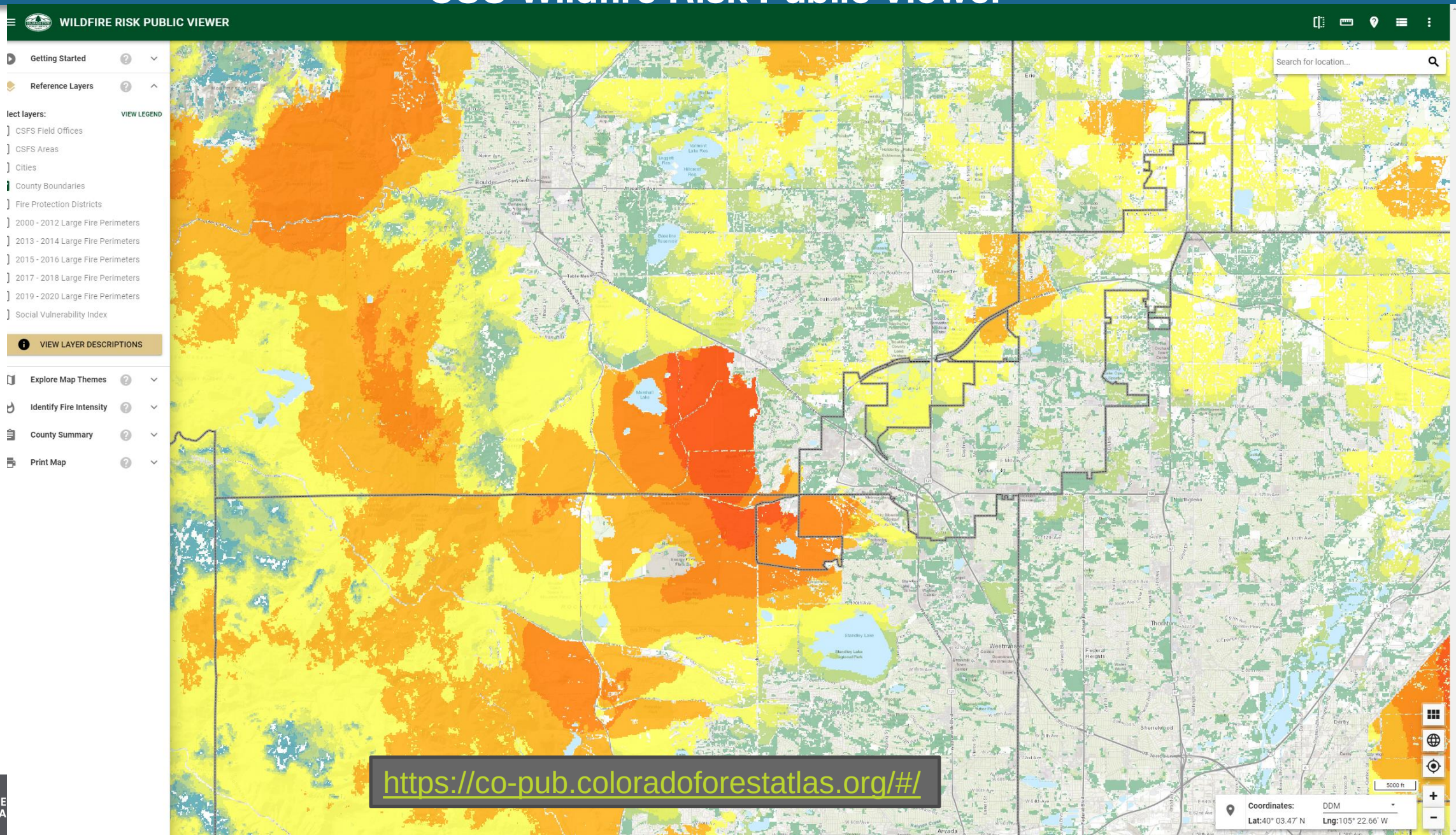
Overview

- Observations
  - Early windstorm
  - Approach of the fire
  - Videos from the neighborhood
  - Observations from the neighborhood
  - Radar imagery
- Timelines for Evacuation and Warning
- Review of fire spread modes in Superior and Louisville
- Discussion
  - Wind-enhanced fire?
  - Urban firestorm?
  - Fire-enhanced windstorm?
- Recommendations

Potential Fire Intensity
CSU Wildfire Risk Public Viewer



WILDFIRE RISK PUBLIC VIEWER

Getting Started

Reference Layers

Select layers: VIEW LEGEND

- [ ] CSFS Field Offices
- [ ] CSFS Areas
- [ ] Cities
- [x] County Boundaries
- [ ] Fire Protection Districts
- [ ] 2000 - 2012 Large Fire Perimeters
- [ ] 2013 - 2014 Large Fire Perimeters
- [ ] 2015 - 2016 Large Fire Perimeters
- [ ] 2017 - 2018 Large Fire Perimeters
- [ ] 2019 - 2020 Large Fire Perimeters
- [ ] Social Vulnerability Index

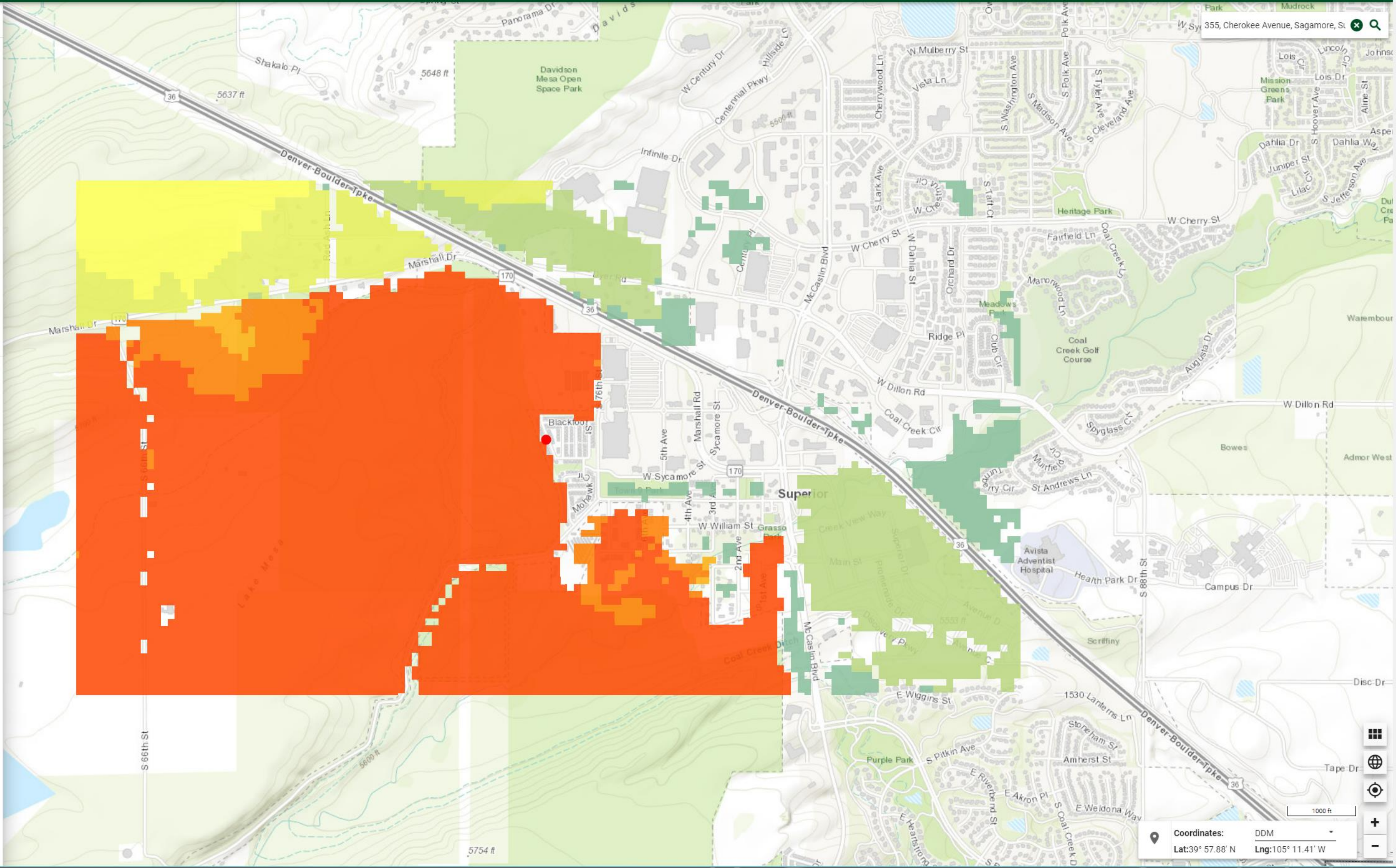
VIEW LAYER DESCRIPTIONS

Explore Map Themes

Identify Fire Intensity

County Summary

Print Map



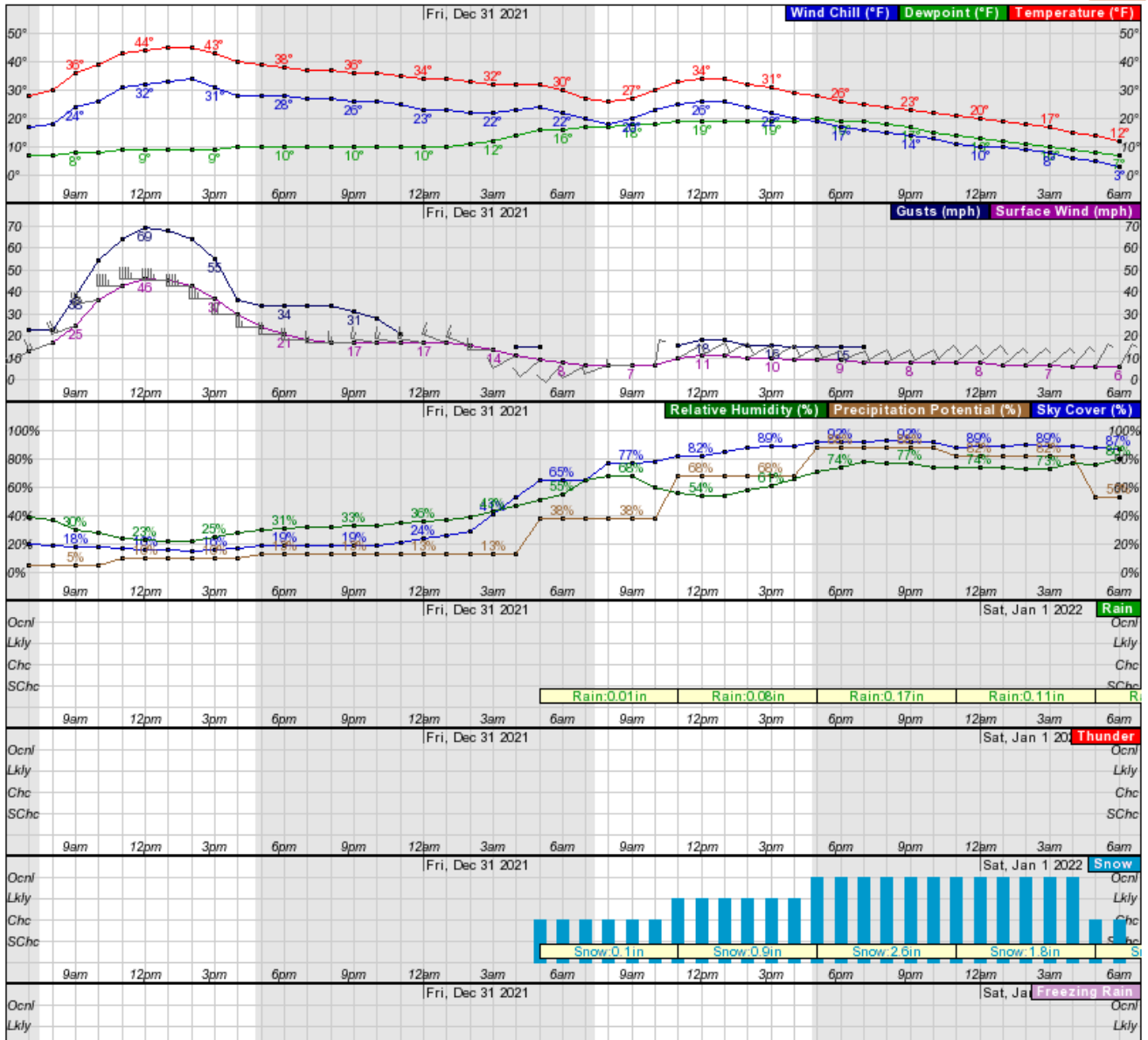
National Weather Service Grid Point Forecast for Superior

Point Forecast: 2 Miles W Louisville CO
39.96N 105.18W (Elev. 5597 ft)

Last Update: 3:54 am MST Dec 30, 2021

Hourly Weather Forecast Graph

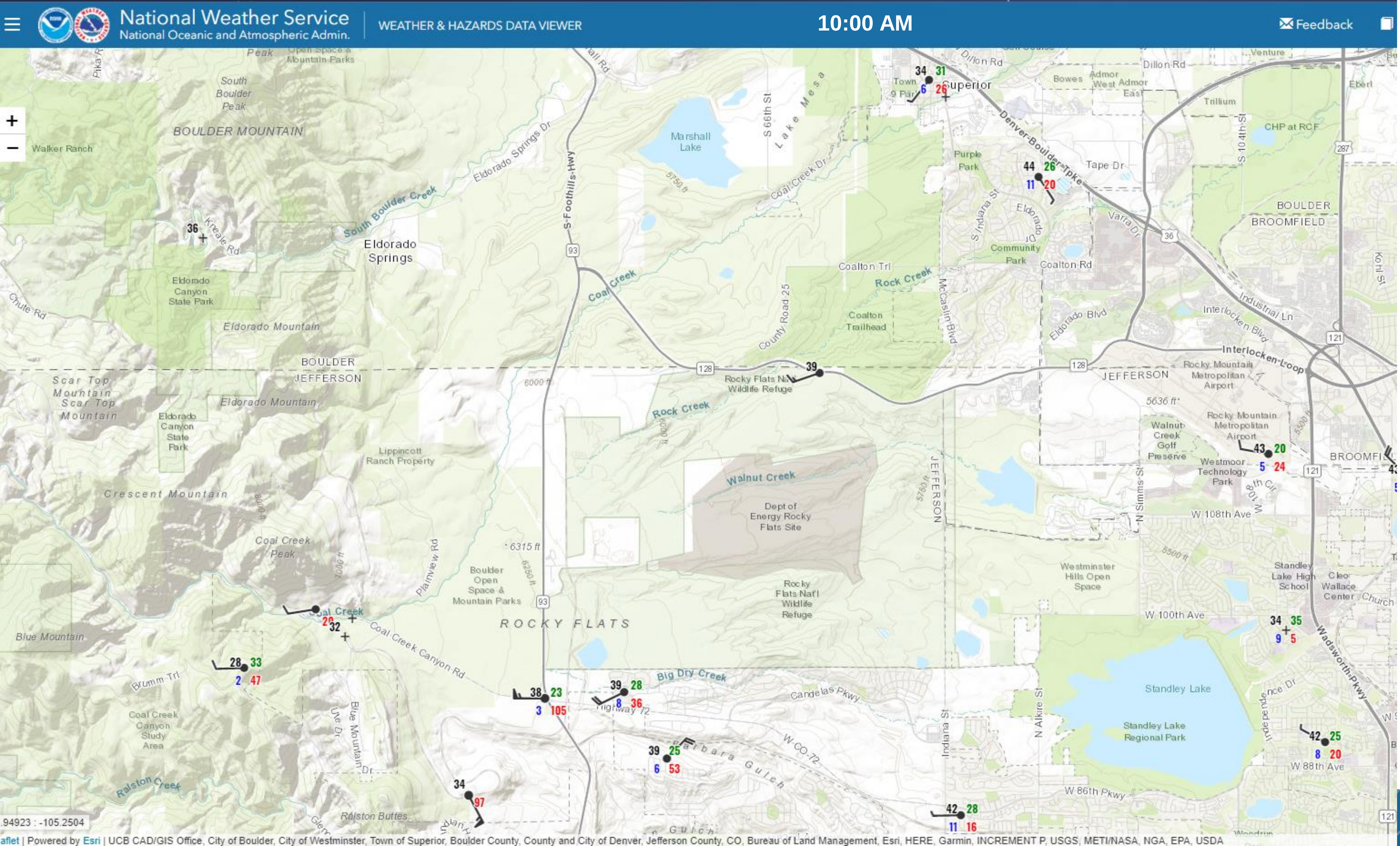
[dashes/dots] | [b/w] | [show menu] XML



Observations: Early Windstorm

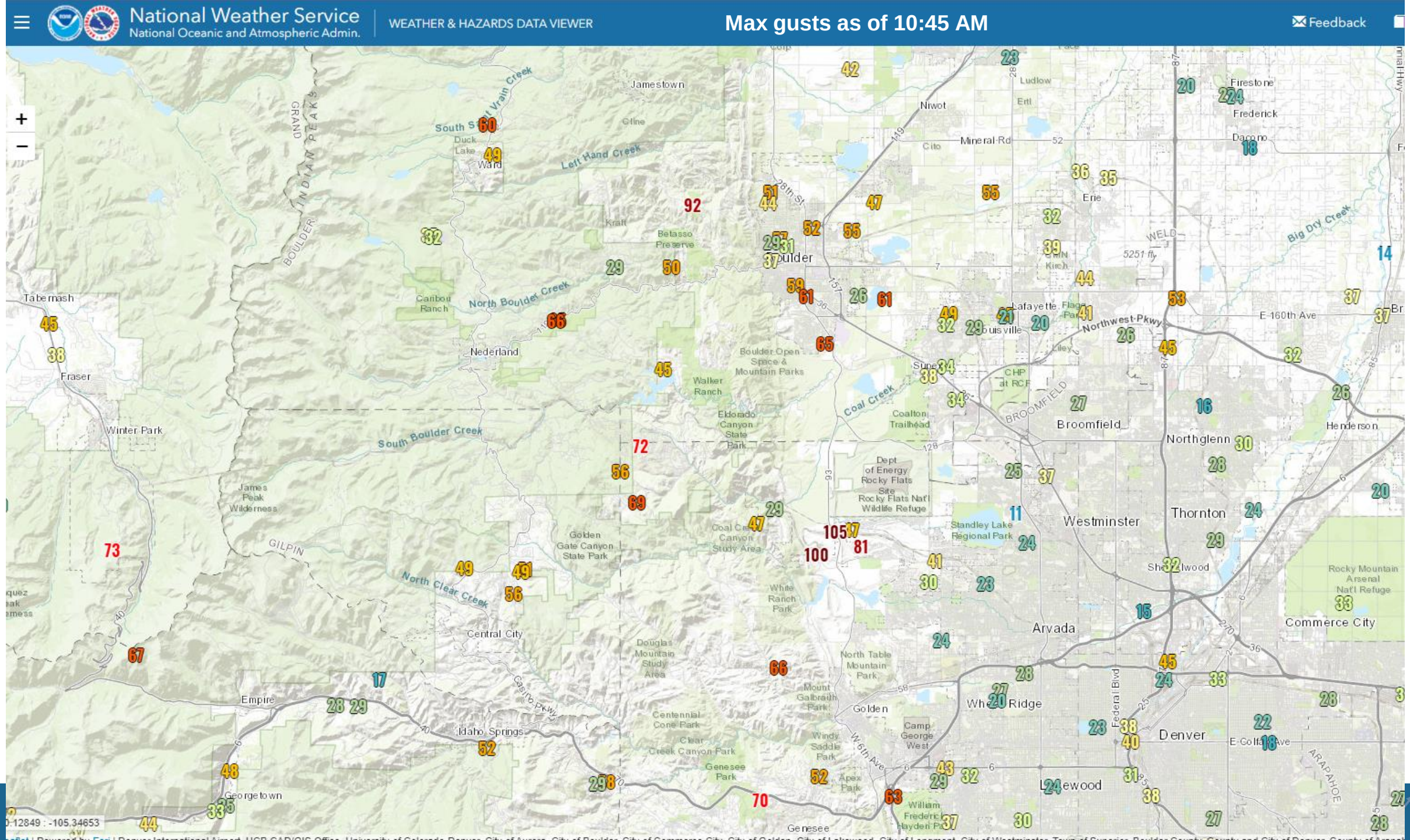
- Windstorm began rather abruptly around 8 AM
- Featured dramatic changes in wind direction at times for the first 1.5 h
  - Around 8:45 AM, a very strong wind out of the South blew the tumbleweeds northward for maybe 30 seconds
  - About a minute or two later, a strong wind out of the north was blowing the opposite directions
  - I remarked to my family that the rotor was likely overhead
- The early portion of the windstorm was rather typical, in which the strongest winds were well to the west of us
- Run-of-the-mill winds of 55-65 mph through ~10 AM

10:00 AM



National Weather Service
National Oceanic and Atmospheric Admin.
WEATHER & HAZARDS DATA VIEWER
Feedback
BOULDER MOUNTAIN
Walker Ranch
South Boulder Peak
Eldorado Springs
South Boulder Creek
Eldorado Springs Dr
S Foothills Hwy
Marshall Lake
Superior
Denver-Boulder Tpke
Purple Park
Community Park
Coalton Rd
Coalton Trl
Rock Creek
Coalton Trailhead
McCaslin Blvd
County Road 25
Coal Creek
Eldorado Canyon State Park
Eldorado Mountain
BOULDER
JEFFERSON
Scar Top Mountain
Rocky Flats Nat'l Wildlife Refuge
Interlocken Loop
Rocky Mountain Metropolitan Airport
BOULDER
BROOMFIELD
Lippincott Ranch Property
Crescent Mountain
Walnut Creek
Dept of Energy Rocky Flats Site
Walnut Creek Golf Preserve
Westmoor Technology Park
W 108th Ave
Coal Creek Peak
Boulder Open Space & Mountain Parks
ROCKY FLATS
Westminster Hills Open Space
Standley Lake High School
Cleo Wallace Center
W 100th Ave
Blue Mountain
Coal Creek Canyon Rd
Big Dry Creek
Candelas Pkwy
Standley Lake
Standley Lake Regional Park
Wadsworth Pkwy
Coal Creek Canyon Study Area
Ralston Creek
Ralston Buttes
W 86th Pkwy
W 88th Ave
Indiana St
N Alkire St
Leaflet | Powered by Esri | UCB CAD/GIS Office, City of Boulder, City of Westminster, Town of Superior, Boulder County, County and City of Denver, Jefferson County, CO, Bureau of Land Management, Esri, HERE, Garmin, INCREMENT P, USGS, METI/NASA, NGA, EPA, USDA


10:07 AM

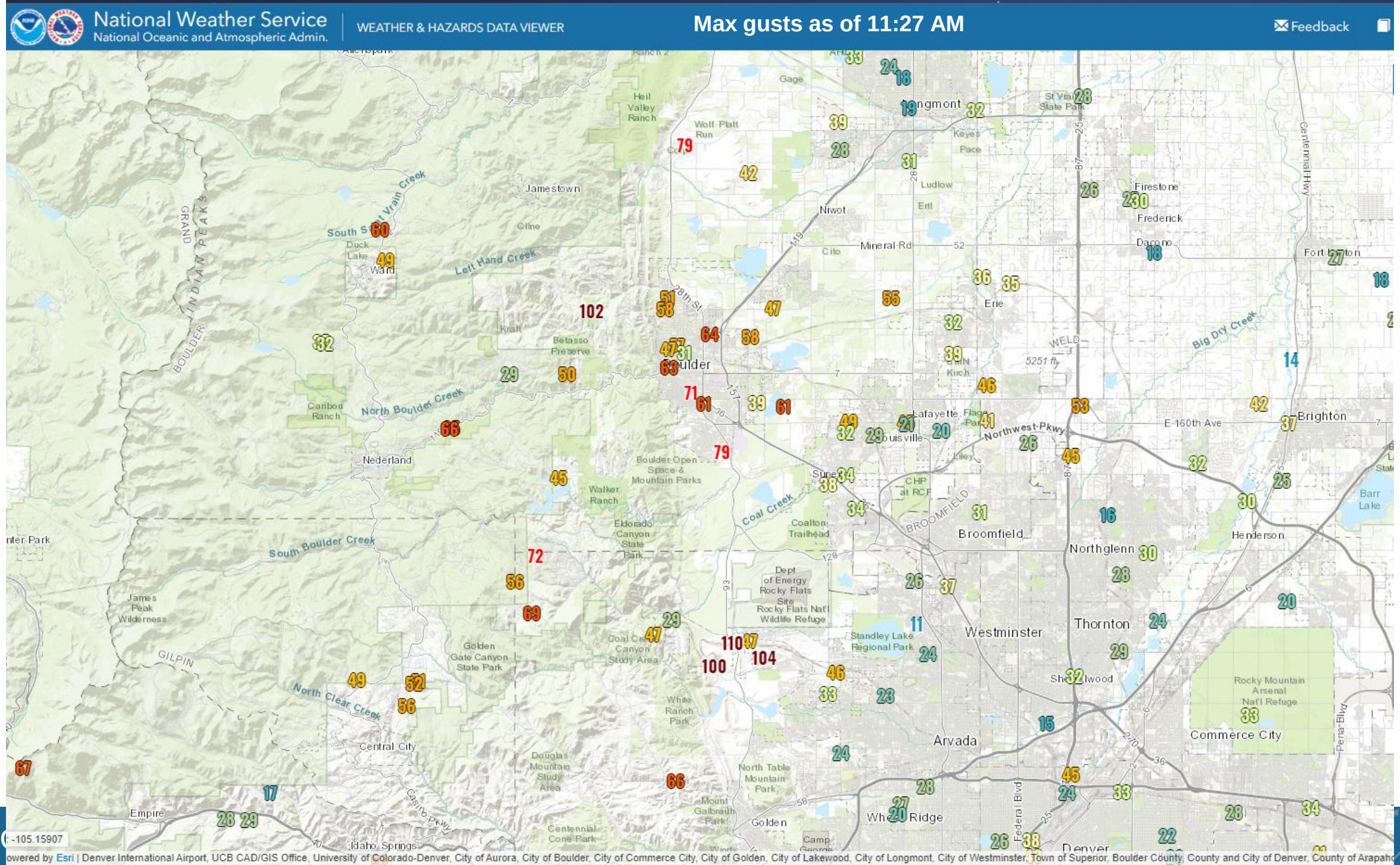

National Weather Service
National Oceanic and Atmospheric Admin.
WEATHER & HAZARDS DATA VIEWER
Max gusts as of 10:45 AM
Feedback
Jamestown
Ward
Left Hand Creek
Niwot
Ludlow
Firestone
Frederick
Dacono
Mineral Rd
Cito
Erie
Krall
Betasso Preserve
Boulder
Big Dry Creek
Tabernash
Fraser
Winter Park
Caribou Ranch
North Boulder Creek
Nederland
Boulder Open Space & Mountain Parks
Walker Ranch
Eldorado Canyon State Park
Coal Creek
Coalton Trailhead
Lafayette
Louisville
Northwest Pkwy
E 160th Ave
Broomfield
Northglenn
Henderson
South Boulder Creek
James Peak Wilderness
Dept of Energy Rocky Flats Site
Rocky Flats Nat'l Wildlife Refuge
Standley Lake Regional Park
Westminster
Thornton
Golden Gate Canyon State Park
Coal Creek Canyon Study Area
GILPIN
North Clear Creek
Central City
White Ranch Park
Arvada
Rocky Mountain Arsenal Nat'l Refuge
Commerce City
Douglas Mountain Study Area
North Table Mountain Park
Empire
Idaho Springs
Mount Galbraith Park
Golden
Centennial Cone Park
Clear Creek Canyon Park
Genesee Park
Windy Saddle Park
Apex Park
Camp George West
Denver
Federal Blvd
E Colfax Ave
Georgetown
Lakewood
William Frederick Hayden Park
Genesee


11:02 AM

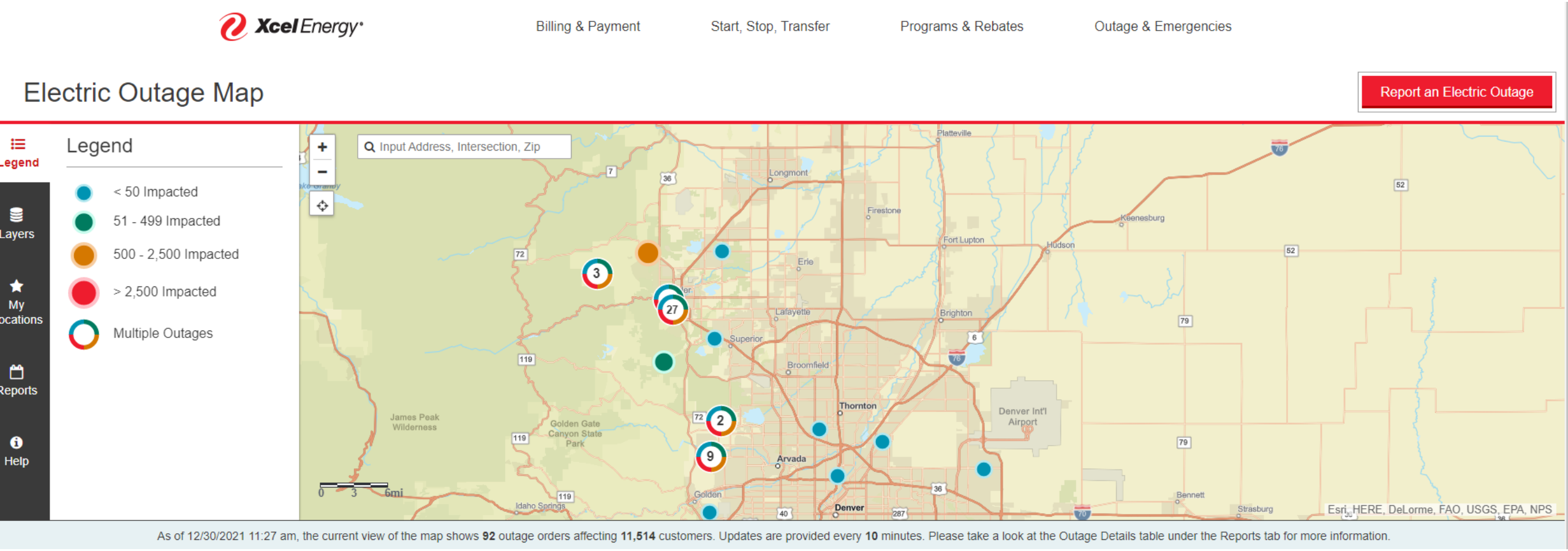

Anjan Sabkota (YouTube, Fox31 News)

CO-109
Hwy-93 and CO-72

30 Dec 1:45 pm	40	4	22	24	W	64G91
30 Dec 1:35 pm	40	4	22	24	W	63G92
30 Dec 1:25 pm	40	2	20	25	W	62G96
30 Dec 1:15 pm	40	1	19	25	W	62G95
30 Dec 1:05 pm	40	1	19	24	W	69G96
30 Dec 12:54 pm	40	2	20	24	W	67G96
30 Dec 12:44 pm	40	2	20	24	W	65G95
30 Dec 12:34 pm	40	2	20	24	W	71G98
30 Dec 12:24 pm	40	3	21	24	W	72G98
30 Dec 12:14 pm	40	4	22	24	W	68G96
30 Dec 12:03 pm	40	5	23	24	W	67G107
30 Dec 11:53 am	40	4	22	24	W	68G100
30 Dec 11:43 am	39	3	22	22	W	77G101
30 Dec 11:33 am	39	3	22	22	W	70G107
30 Dec 11:23 am	40	3	21	23	W	76G110
30 Dec 11:12 am	39	2	21	22	W	73G102
30 Dec 11:02 am	39	2	21	22	W	75G104
30 Dec 10:52 am	39	3	22	23	SW	68G99
30 Dec 10:42 am	39	2	21	22	W	73G97
30 Dec 10:32 am	39	4	23	22	W	69G100
30 Dec 10:21 am	38	4	23	21	W	69G100
30 Dec 10:11 am	38	5	24	21	W	64G95


National Weather Service
National Oceanic and Atmospheric Admin.
WEATHER & HAZARDS DATA VIEWER
Max gusts as of 11:27 AM
Feedback
Longmont
Niwot
Jamestown
Cline
Ward
Left Hand Creek
South St Vrain Creek
Boulder
Nederland
North Boulder Creek
South Boulder Creek
Coal Creek
Lafayette
Louisville
Erie
Broomfield
Westminster
Thornton
Northglenn
Arvada
Commerce City
Brighton
Henderson
Golden
Central City
Idaho Springs
Empire
Mineral Rd
Northwest Pkwy
E 160th Ave
Firestone
Frederick
Dacono
Fort Lupton
Big Dry Creek
Standley Lake Regional Park
Rocky Mountain Arsenal Nat'l Refuge
Barr Lake
Boulder Open Space & Mountain Parks
Eldorado Canyon State Park
Golden Gate Canyon State Park
Dept of Energy Rocky Flats Site
Rocky Flats Nat'l Wildlife Refuge
Coalton Trailhead
Walker Ranch
Caribou Ranch
Betasso Preserve
James Peak Wilderness
North Clear Creek
Clear Creek Canyon Study Area
White Ranch Park
North Table Mountain Park
Mount Galbraith Park
Centennial Cone Park
Douglas Mountain Study Area
Golden
Wheat Ridge
Federal Blvd
Pena Blvd
Centennial Hwy
BROOMFIELD
GILPIN
BOULDER
GRAND
INDIAN PEAKS
WELD
Feedback
-105.15907
Powered by Esri | Denver International Airport, UCB CAD/GIS Office, University of Colorado-Denver, City of Aurora, City of Boulder, City of Commerce City, City of Golden, City of Lakewood, City of Longmont, City of Westminster, Town of Superior, Boulder County, County and City of Denver, County of Arapaho

Power Outage Map @ 11:33 AM



As of 12/30/2021 11:27 am, the current view of the map shows **92** outage orders affecting **11,514** customers. Updates are provided every **10** minutes. Please take a look at the Outage Details table under the Reports tab for more information.

Observations: Approach of the Fire


11:54 AM


Rob Kelly (YouTube)

Approach of the Fire

Video credit: Makia Minich
https://www.youtube.com/watch?v=-dT9D5zrBbs&t=1s&ab_channel=UnknownOverland

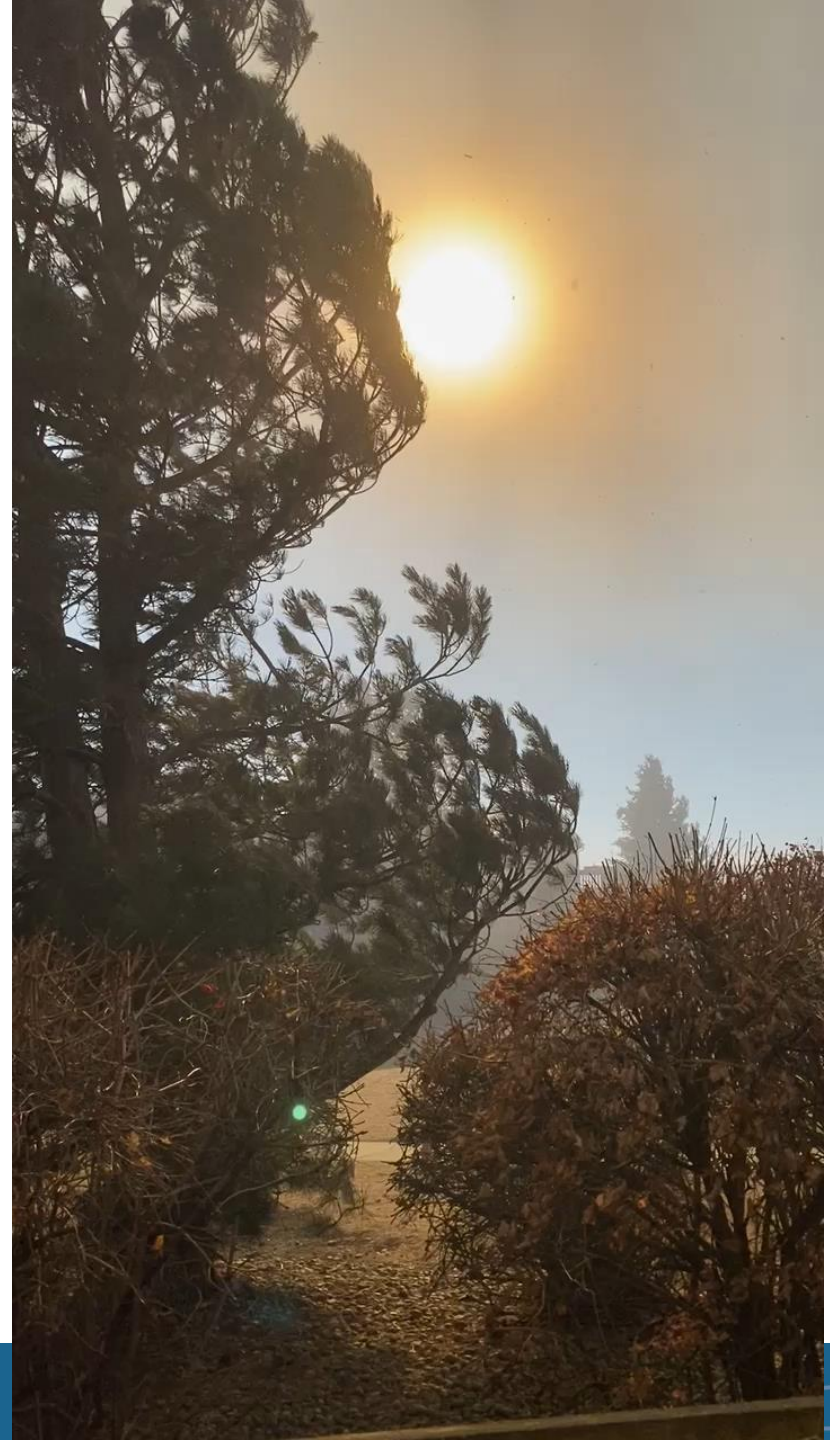
Photo/video sequence by Elena Familetto

11:55 AM

Video by Elena Familetto
12:02 PM

Video by Elena Familetto
12:04 PM

Video by Elena Familetto
12:05 PM



Video by Elena Familetto
12:06 PM

Video by Elena Familetto
12:07 PM


12:08 PM

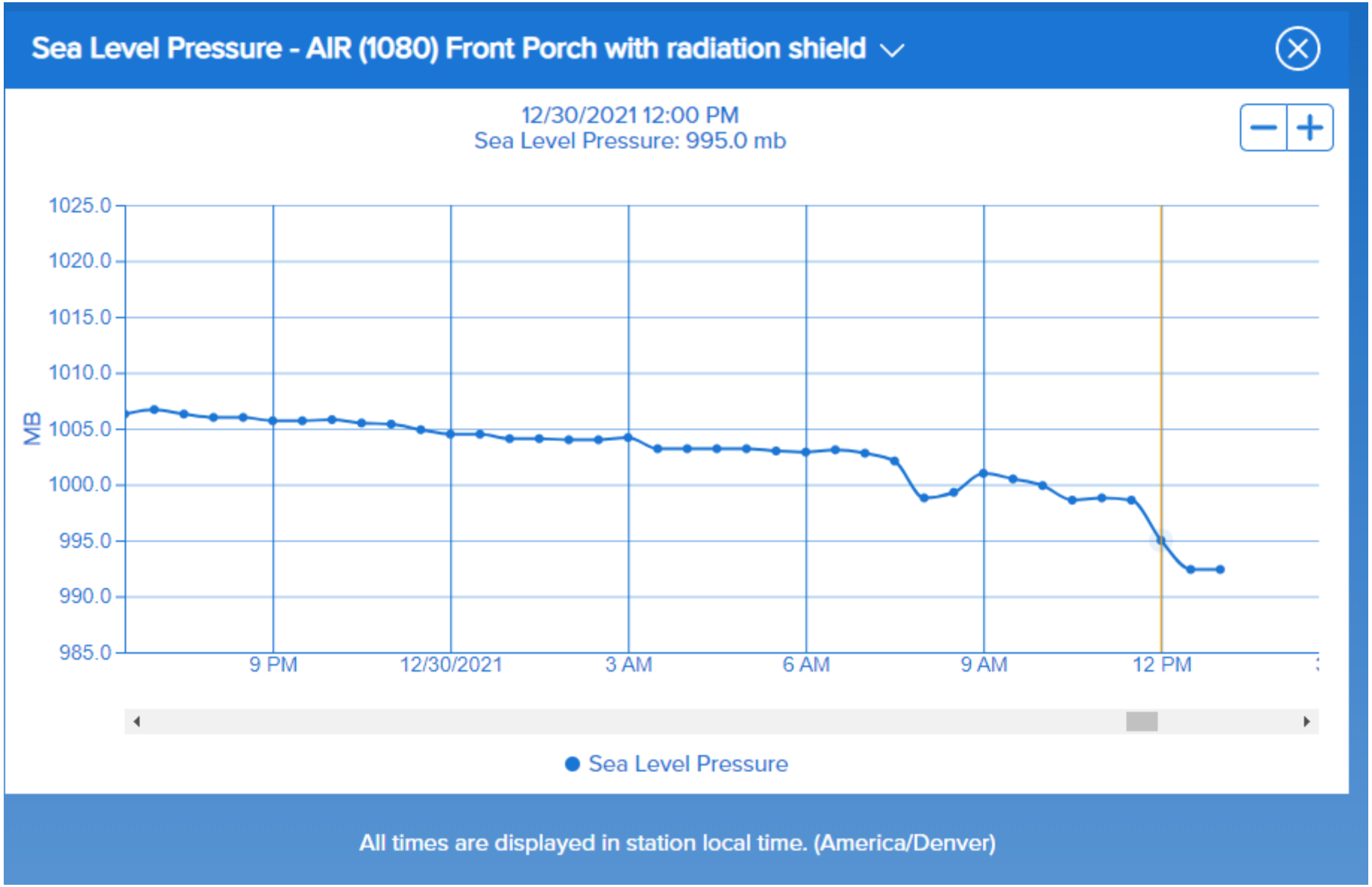
Photo by Elena Familetto
12:10 PM

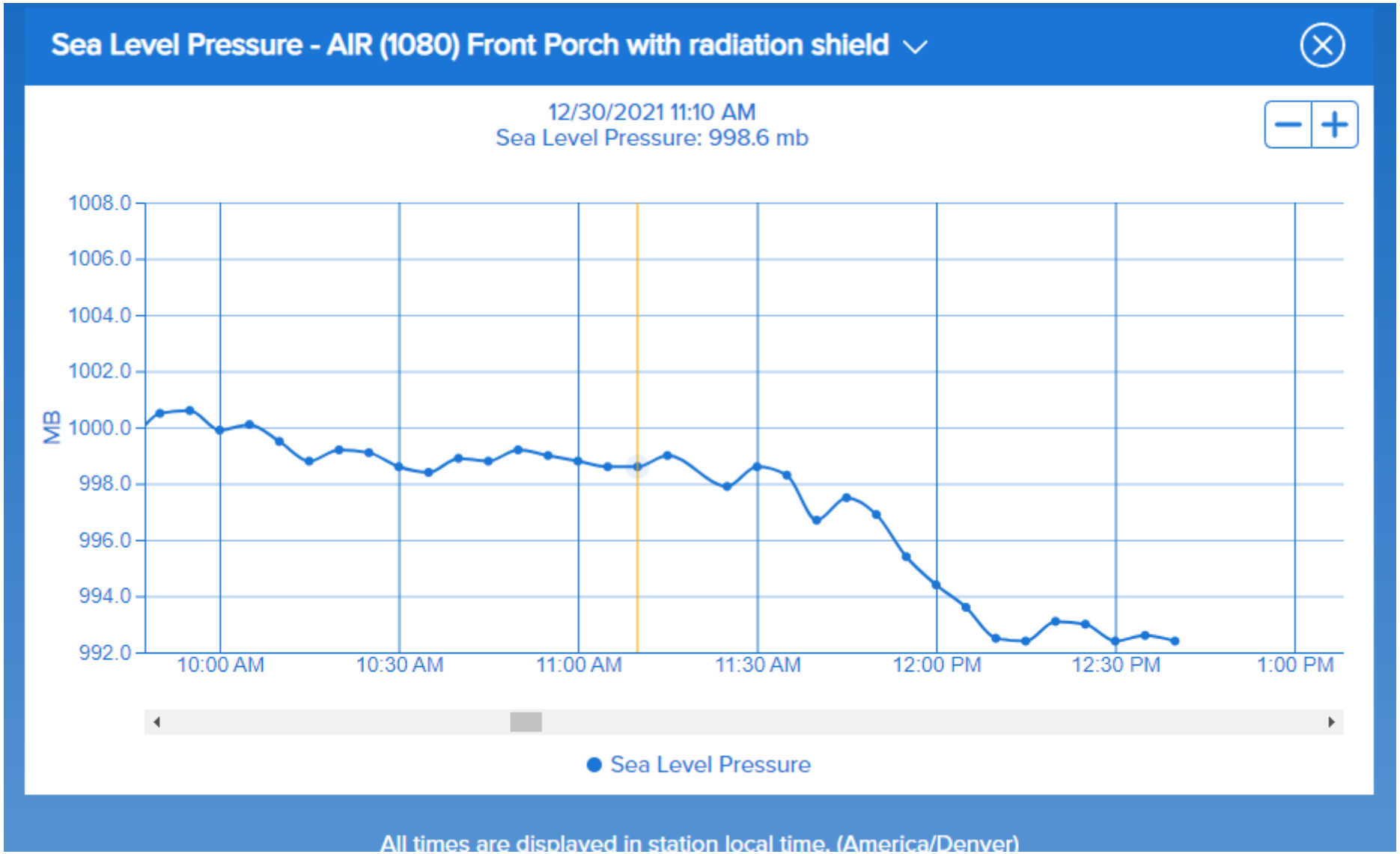
Observations of the Fire Arrival

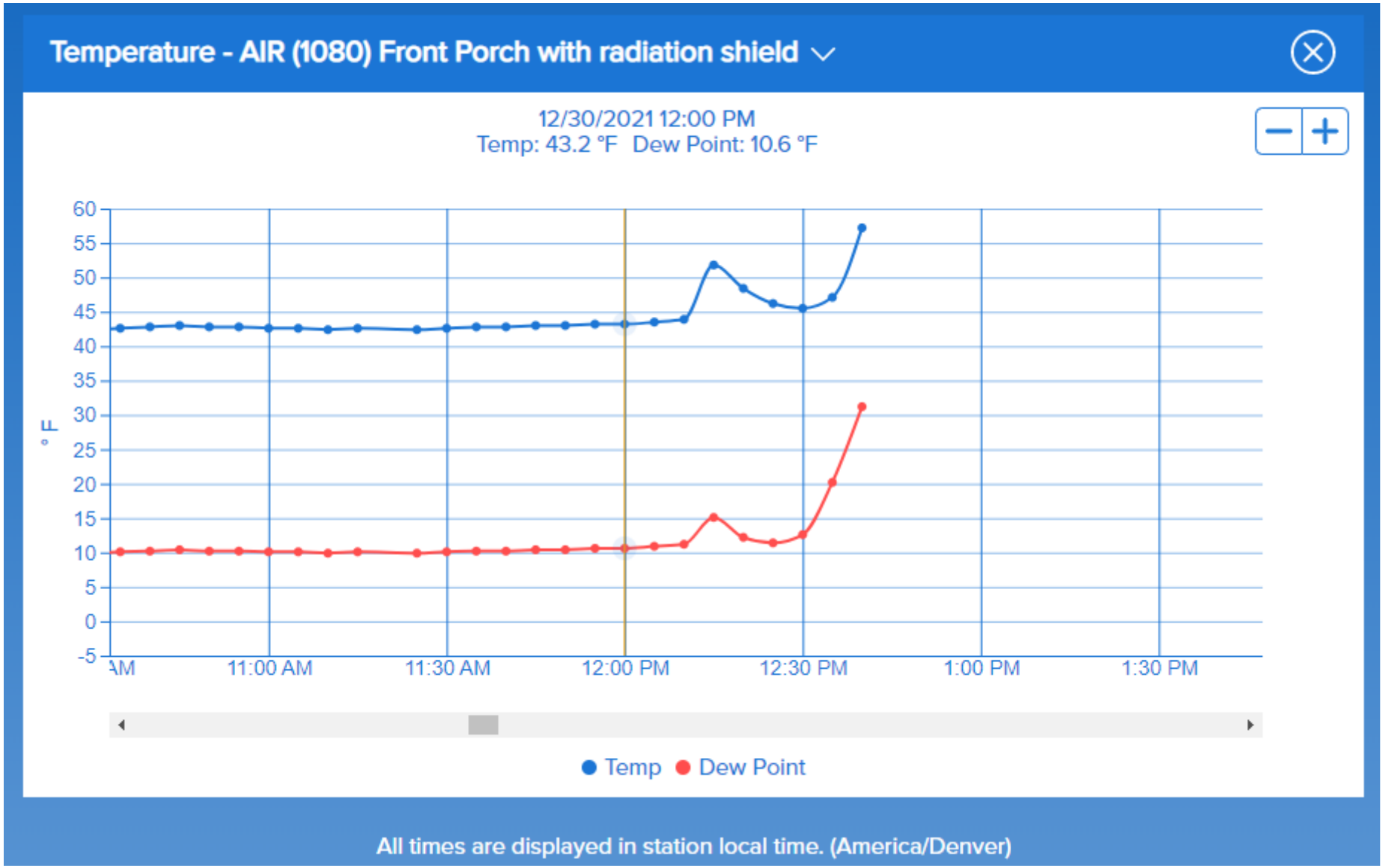
- My instrumentation:
  - Davis Instruments Vantage Pro2
    - Anemometer on a tripod mast 7 ft above the roof crest at a height of 33 ft above the ground
    - Integrated sensor suite in the backyard at 5-6 ft
  - WeatherFlow (predecessor to Tempest)
    - Anemometer co-located with Vantage Pro2
    - Temperature sensor on front-porch railing in radiation shield

- My neighbor's instrumentation:
  - Consumer-grade station (Ambient?)
  - Mounted at about 6' on the top of a fence in back corner of yard
  - Winds likely sheltered by proximity to the top of the fence

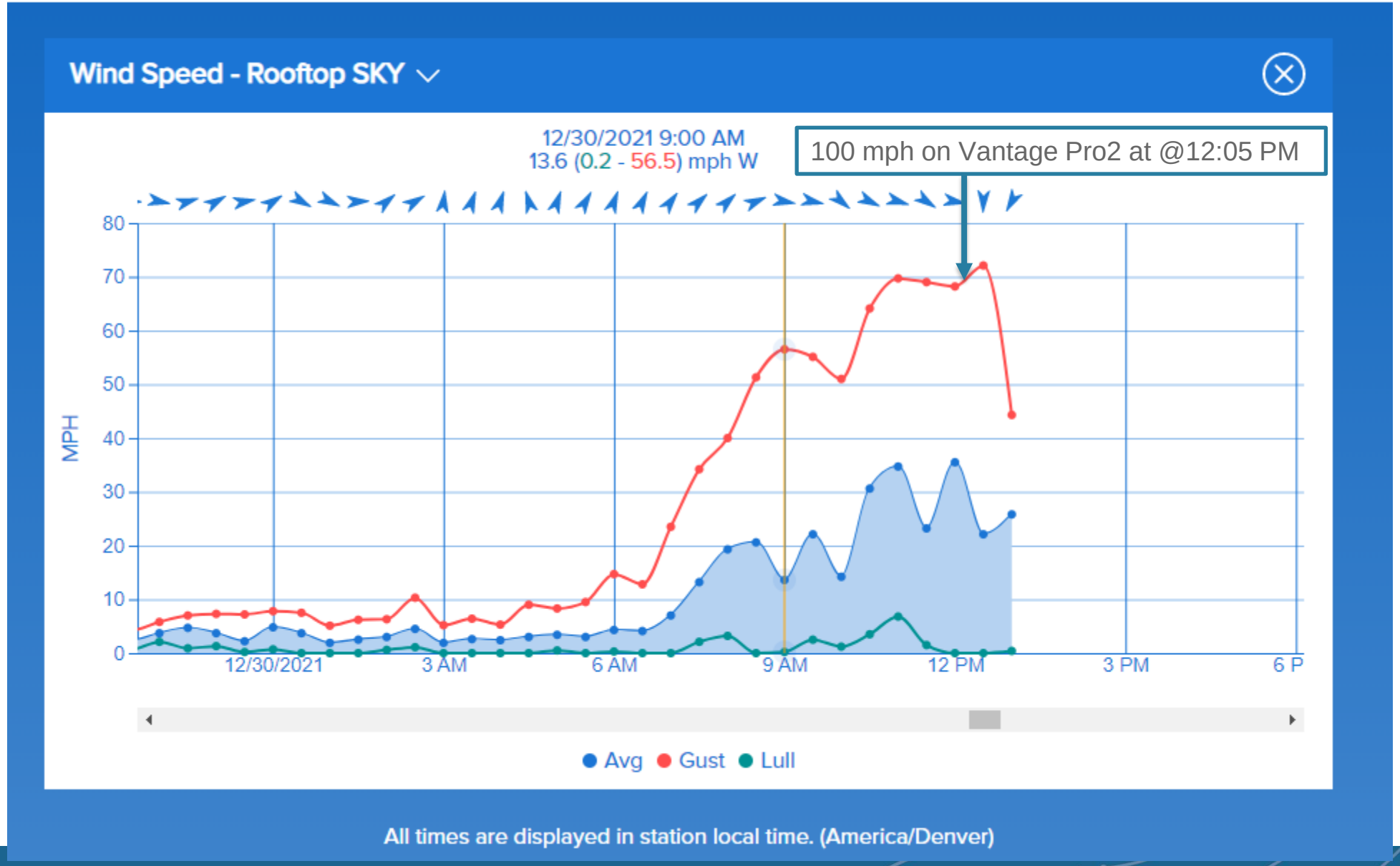

720-791-8409

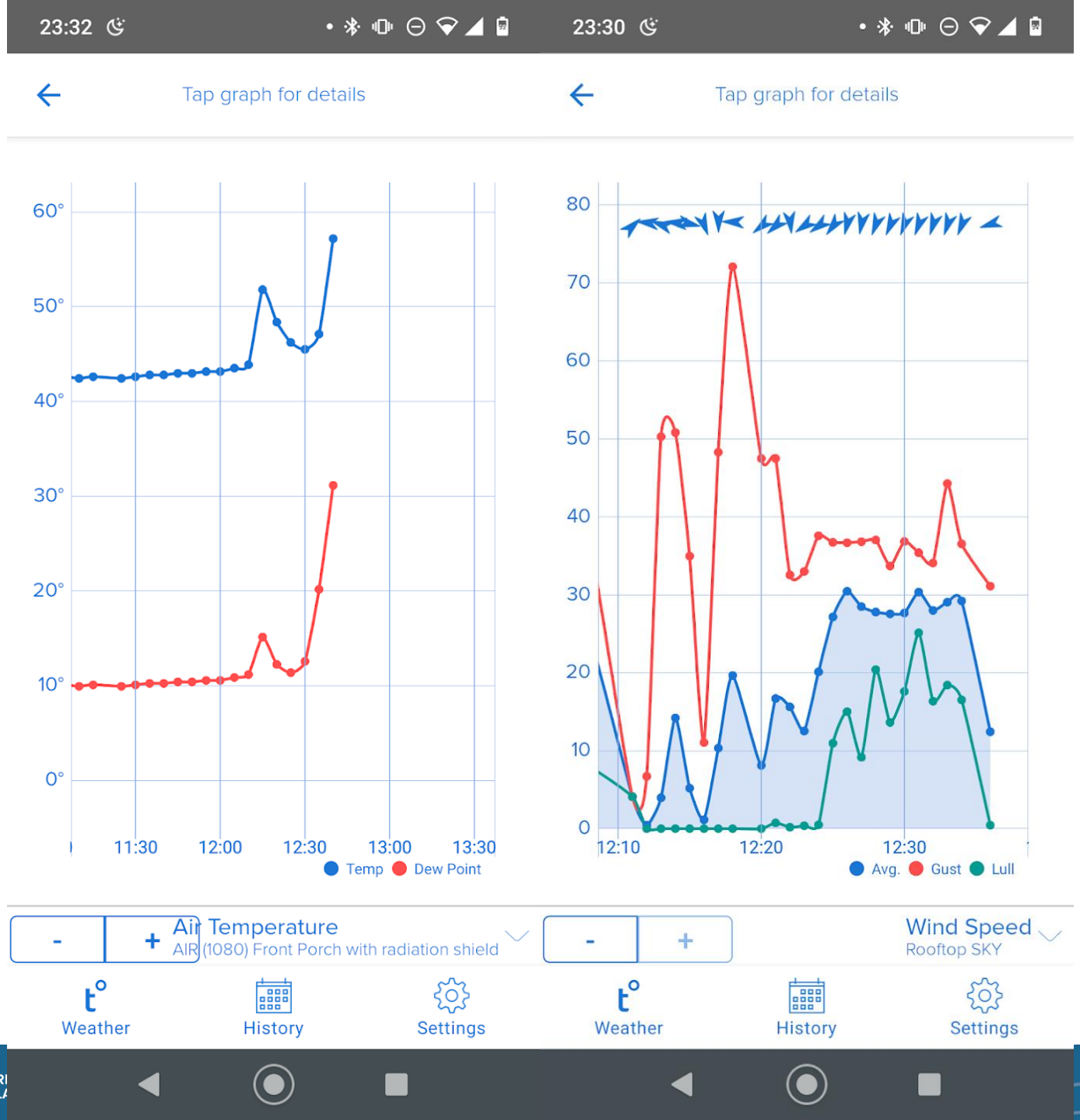

Sea Level Pressure - AIR (1080) Front Porch with radiation shield
12/30/2021 12:00 PM
Sea Level Pressure: 995.0 mb
1025.0
1020.0
1015.0
1010.0
1005.0
1000.0
995.0
990.0
985.0
MB
9 PM
12/30/2021
3 AM
6 AM
9 AM
12 PM
Sea Level Pressure
All times are displayed in station local time. (America/Denver)


Sea Level Pressure - AIR (1080) Front Porch with radiation shield
12/30/2021 11:10 AM
Sea Level Pressure: 998.6 mb
1008.0
1006.0
1004.0
1002.0
1000.0
998.0
996.0
994.0
992.0
MB
10:00 AM
10:30 AM
11:00 AM
11:30 AM
12:00 PM
12:30 PM
1:00 PM
Sea Level Pressure
All times are displayed in station local time. (America/Denver)

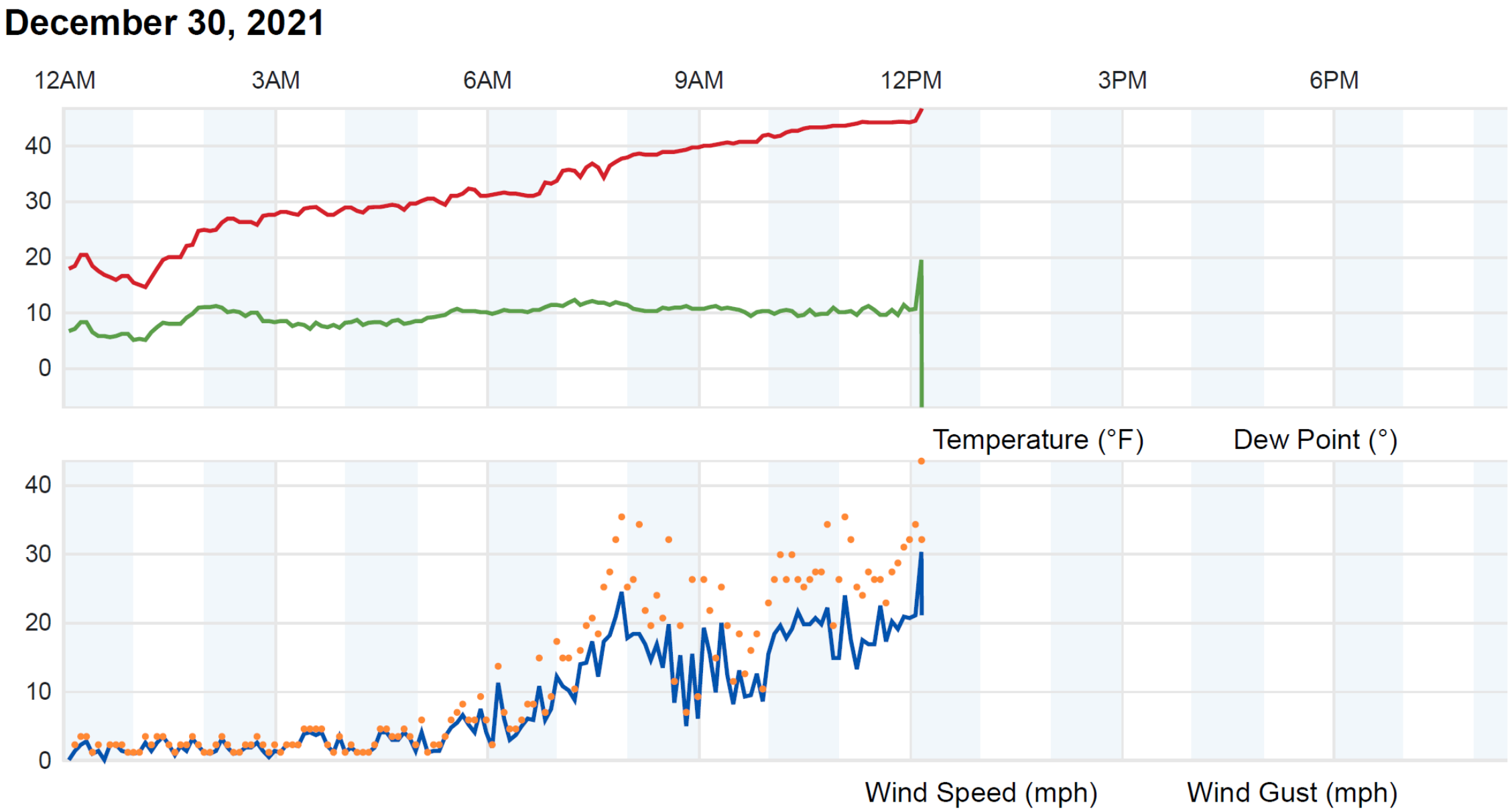

Temperature - AIR (1080) Front Porch with radiation shield
12/30/2021 12:00 PM
Temp: 43.2 °F Dew Point: 10.6 °F
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
° F
AM
11:00 AM
11:30 AM
12:00 PM
12:30 PM
1:00 PM
1:30 PM
Temp
Dew Point
All times are displayed in station local time. (America/Denver)

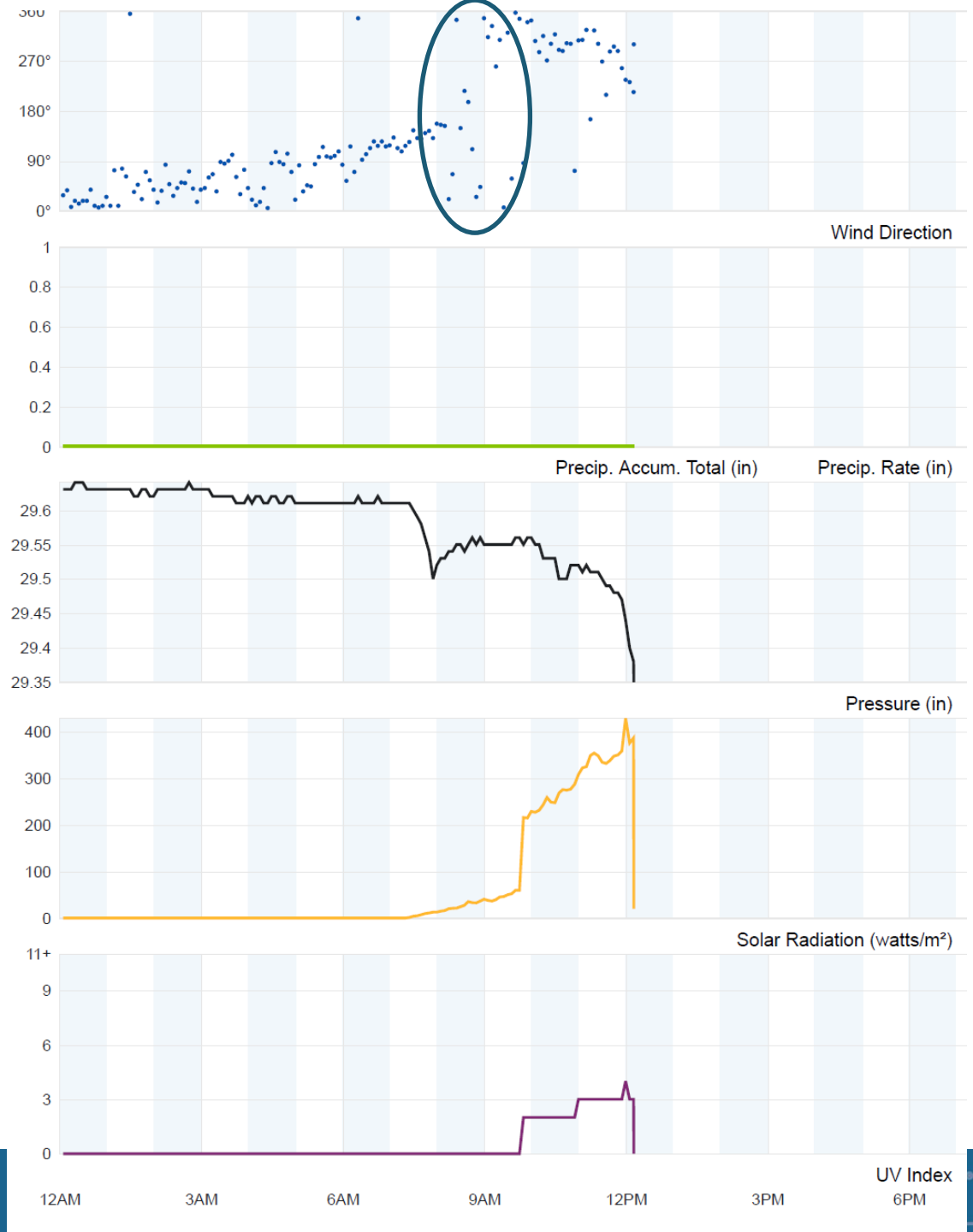
History


Wind Speed - Rooftop SKY
12/30/2021 9:00 AM
13.6 (0.2 - 56.5) mph W
100 mph on Vantage Pro2 at @12:05 PM
MPH
80
70
60
50
40
30
20
10
0
12/30/2021
3 AM
6 AM
9 AM
12 PM
3 PM
6 P
Avg
Gust
Lull
All times are displayed in station local time. (America/Denver)


23:32
Tap graph for details
60°
50°
40°
30°
20°
10°
0°
11:30
12:00
12:30
13:00
13:30
Temp
Dew Point
-
+
Air Temperature
AIR (1080) Front Porch with radiation shield
Weather
History
Settings
23:30
Tap graph for details
80
70
60
50
40
30
20
10
0
12:10
12:20
12:30
Avg.
Gust
Lull
-
+
Wind Speed
Rooftop SKY
Weather
History
Settings

Observations from the Neighbor's Station (KCOLOUIS54)




360
270°
180°
90°
0°
Wind Direction
1
0.8
0.6
0.4
0.2
0
Precip. Accum. Total (in)
Precip. Rate (in)
29.6
29.55
29.5
29.45
29.4
29.35
Pressure (in)
400
300
200
100
0
Solar Radiation (watts/m²)
11+
9
6
3
0
UV Index
12AM
3AM
6AM
9AM
12PM
3PM
6PM

Summary
December 30, 2021

	High	Low	Average
Temperature	**46.6** °F	**14.4** °F	**31.9** °F
Dew Point	**19.4** °F	**-7.1** °F	**8.9** °F
Humidity	**66** %	**10** %	**40** %
Precipitation	**0.00** in	**--**	**--**

	High	Low	Average
Wind Speed	**30.2** mph	**0.0** mph	**5.0** mph
Wind Gust	**43.4** mph	--	**7.0** mph
Wind Direction	**--**	**--**	**East**
Pressure	**29.64** in	**29.35** in	**--**

Photo by Brian Giles

Last Report of my Tempest

A pause for some dynamical interpretation

- Streamwise vorticity generated by the updraft bending up the horizontal axis roll vorticity downstream of the plume?
- Or something else related to structure of the windstorm?

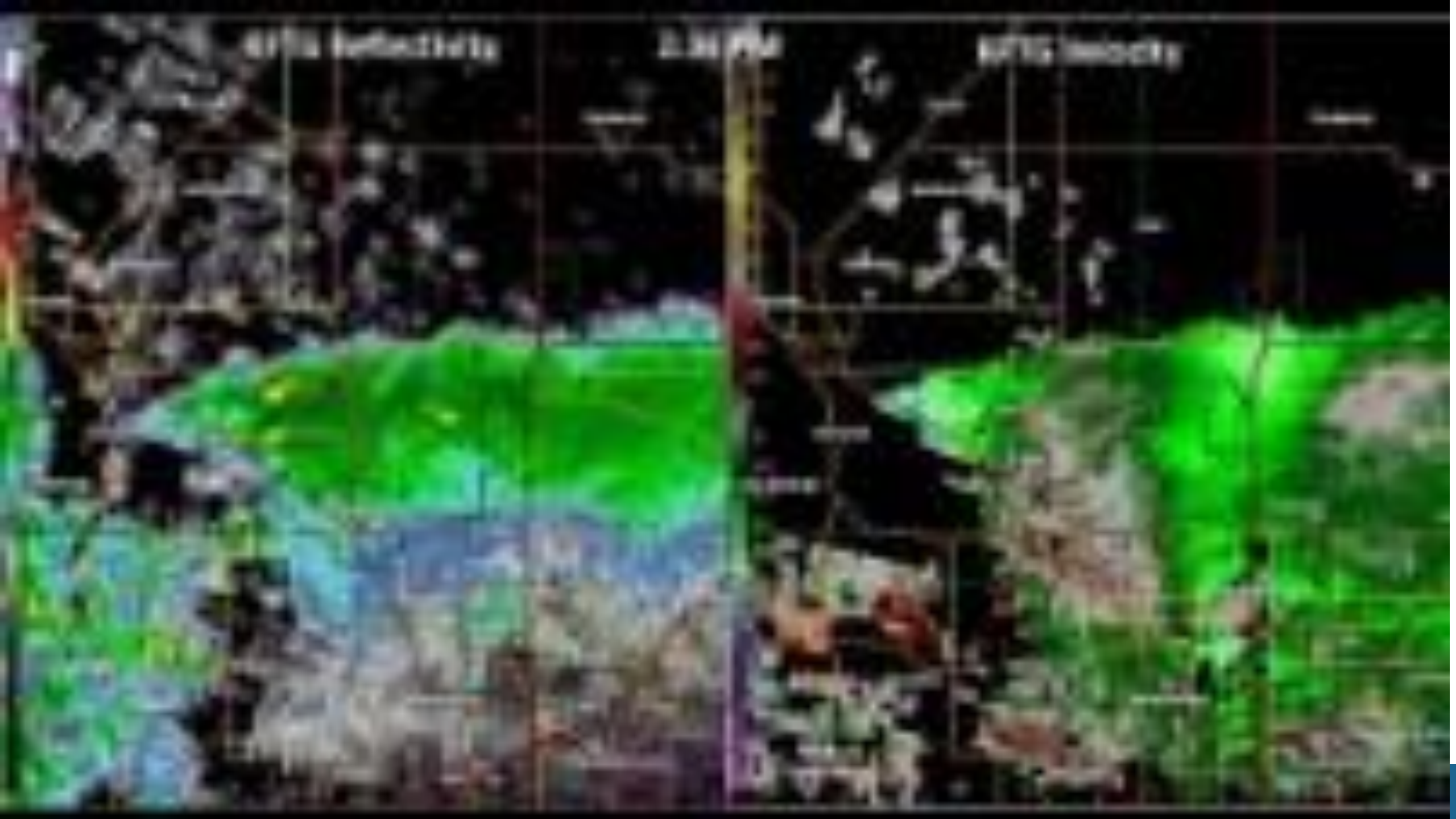
DENVER7 | BREAKING NEWS

LIFE-THREATENING FIRES

WIND FUELS TERRIBLE CONDITIONS IN BOULDER, SUPERIOR

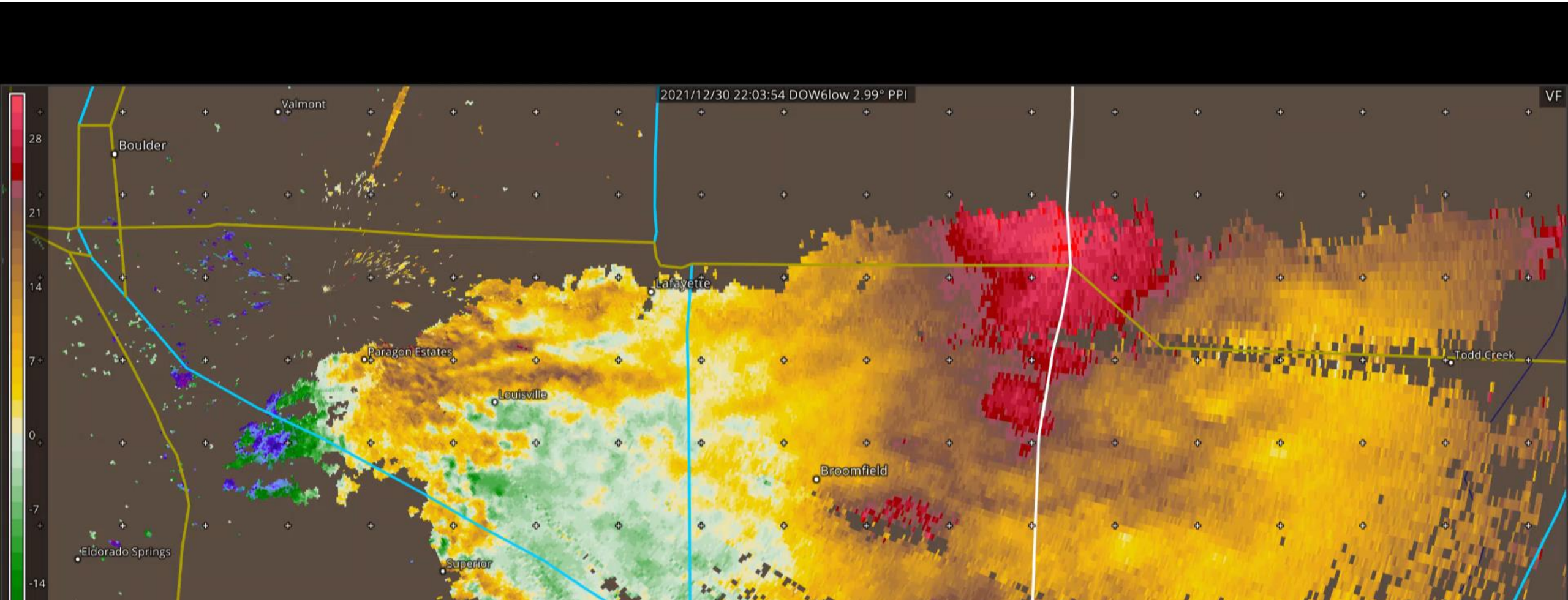
1:06
46°

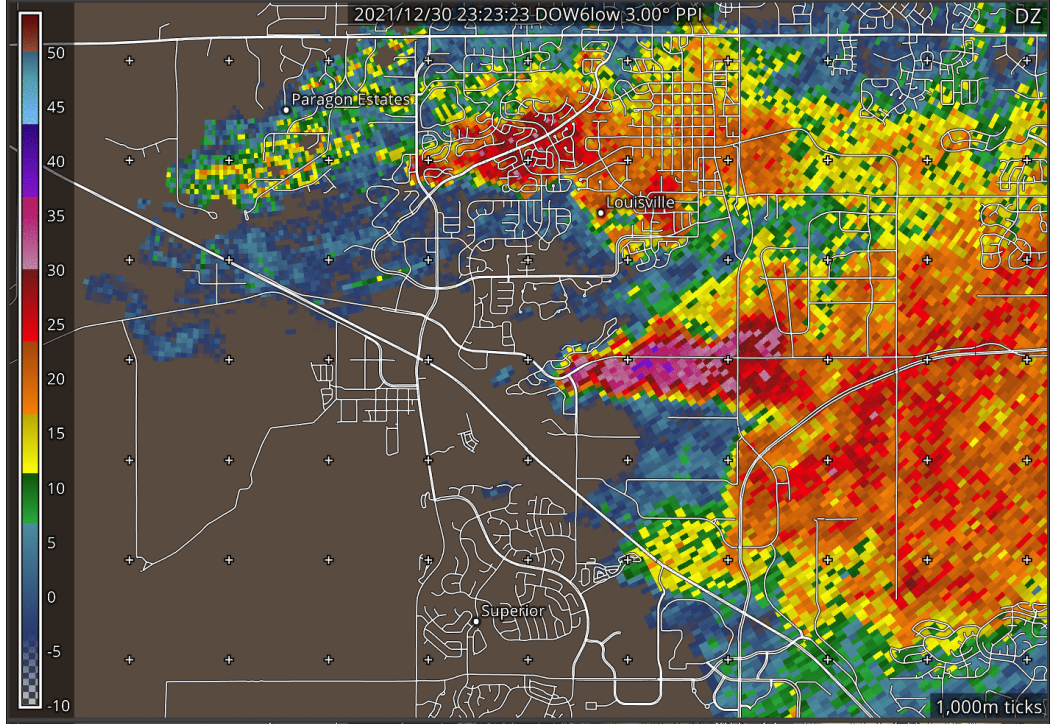
DENVER 7 abc

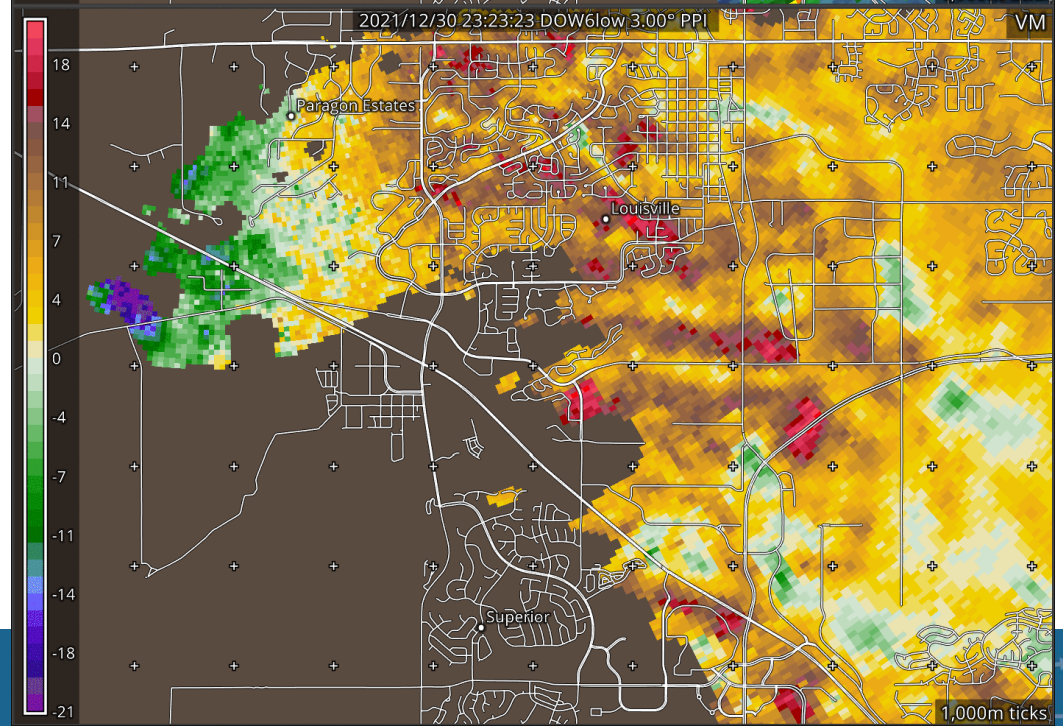


Doppler on Wheels (DOW) Observations
Thanks to Karen Kosiba (CSWR)

- From later in the event

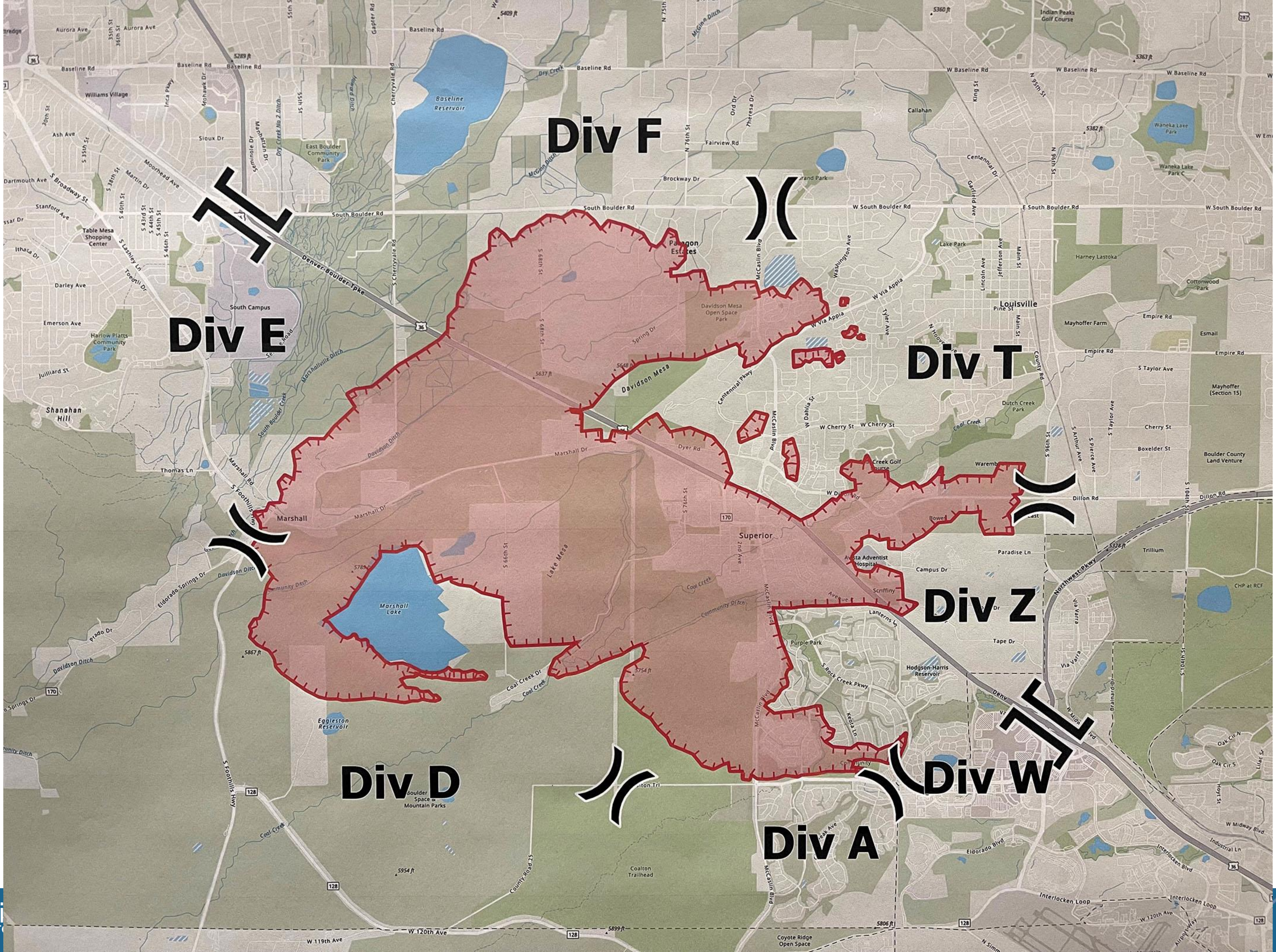



2021/12/30 23:23:23 DOW6low 3.00° PPI
DZ
50
45
40
35
30
25
20
15
10
5
0
-5
-10
Paragon Estates
Louisville
Superior
1,000m ticks


2021/12/30 23:23:23 DOW6low 3.00° PPI
VM
18
14
11
7
4
0
-4
-7
-11
-14
-18
-21
Paragon Estates
Louisville
Superior
1,000m ticks

View of Smoke Plume from Louisville

Video by Lisa Young's husband @ 12:18 PM


Div F
Div E
Div T
Div Z
Div D
Div A
Div W
Baseline Reservoir
South Boulder Rd
Baseline Rd
Denver-Boulder Tpke
South Campus
Davidson Mesa
Louisville
Marshall
Superior
Marshall Lake
Eggleston Reservoir
Hodgson-Harris Reservoir
Dillon Rd
W 120th Ave
Coalton Trailhead
Harney Lastoka
Mayhoffer Farm
Waneka Lake Park
Shanahan Hill

Progression of fire into Louisville

Photo by Lisa Young

Grass fire @ 1:58 PM

2:17 PM?

https://www.facebook.com/patrick.kramer.35325/videos/350138813587415/

The Aftermath

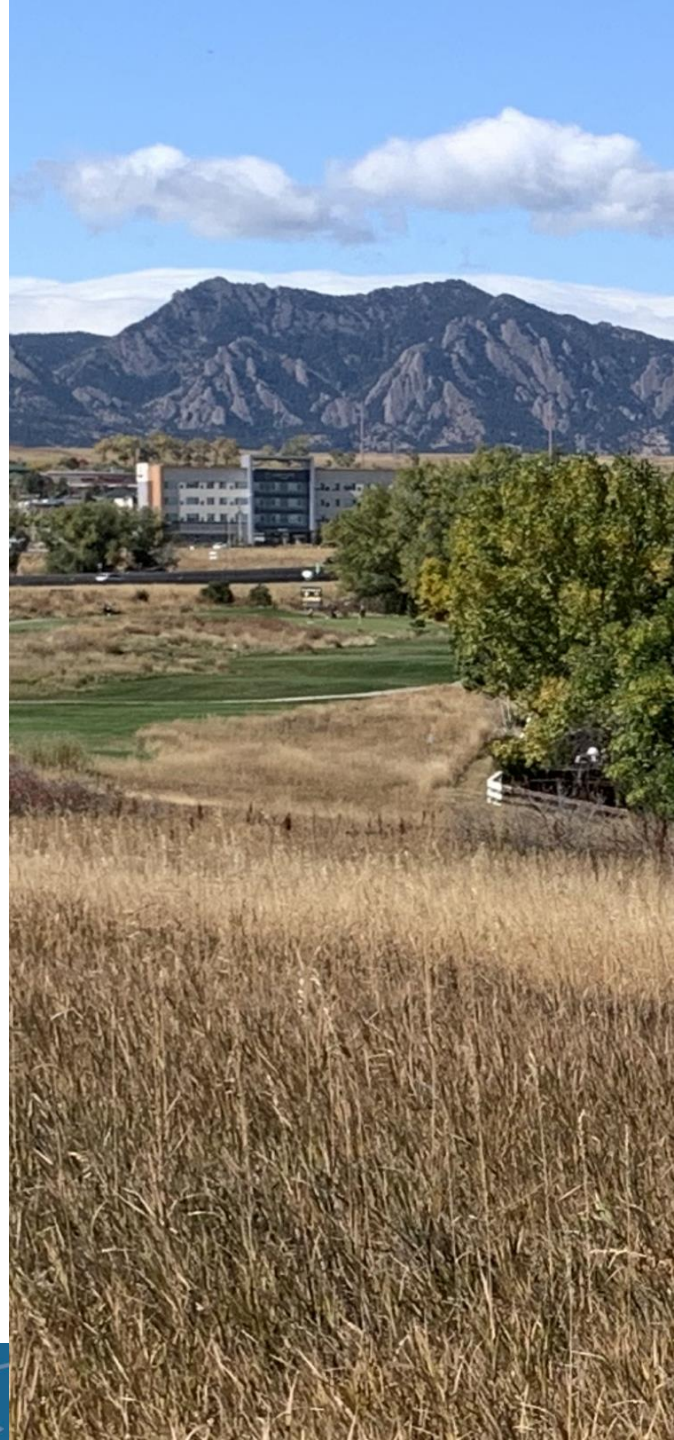
Fire Investigation on January 13
Insurance Institute for Business & Home Safety (IBHS)

- A national team of experts was assembled to examine the modes of fire spread and impact on structures. The team included representatives from IBHS, Boulder County's Firewise Program, several university professors and post-docs, and at least one representative from the reinsurance industry.

Role of Grass – Oct 20, 2021

- Mature, thick grasses
- Only mowed within ~6 ft of fences
- Residents not allowed to mow grasses in open space behind their properties

Photos by Lisa Young




11:54 AM

Review of Fire Spread Modes

- Once in the WUI, fire spread through a mixture of discontinuous fuels and via ember showers
- Normally, burning grass produces embers that are not large enough to catch a house on fire
- When the grass fire got to Sagamore, there were some tumbleweeds which had accumulated against the dual fences between the open space and the abandoned railroad right-of-way. One resident describes these catching fire and getting lofted in the wind as "**firebombs**". These larger weeds likely led to the embers that caught the houses on fire, whether through the attic, decks, or from igniting vegetation near the house
  - Once one house went, all adjacent houses were practically guaranteed to be lost due to the 10' spacing between houses and lack of effective firefighting in Sagamore that day (due to high winds, low water pressure)
    - houses can catch fire from radiant heat of a house burning even 25 feet away
  - Due to the proximity of houses and very flammable exterior materials, there was little hope to save the neighborhood
- Sagamore burning down in 100+ mph winds lead to a huge ember shower which likely traveled for thousands of feet, igniting structures in Original Town, Coal Creek Crossing, and the Elements Hotel.
- Embers from these new burning locations may have sparked the grass fires which raced up through the open space in Louisville to Coal Creek Ranch and St. Andrews Lane, etc. Any larger weeds likely contributed to local embers which caught people's decks on fire, etc. But long-distance embers also likely contributed to catching homes on fire
- More burning houses in Louisville contributed to more large embers, and so on
- Fire spread via grass stopped near Monarch High School where the grasses were trimmed very short
- In some areas, homes burned down hours after the grass fire went through due to spot fires (e.g., in Rock Creek and some parts of Louisville). Wooden fences played a role in propagating these spot fires to houses in some cases

European Geosciences Union

Atmospheric Chemistry and Physics

Atmos. Chem. Phys., 7, 645–659, 2007
https://doi.org/10.5194/acp-7-645-2007

09 Feb 2007

The Chisholm firestorm: observed microstructure, precipitation and lightning activity of a pyro-cumulonimbus

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Abstract. A fire storm that occurred on 28 May 2001 and devastated the town of Chisholm, ~150 km north of Edmonton, Alberta, induced a violent fire-invigorated cumulonimbus cloud. This pyro-cumulonimbus (pyro-Cb) had overshooting tops of 2.5–3 km above the tropopause, and injected massive amounts of smoke into the lower stratosphere. Fortunately, this event occurred under good coverage of radar, rain gauge, lightning and satellite measurements, which allowed in-depth documentation of the event, and gave us an opportunity to study the cloud top morphology and microstructure, precipitation and cloud electrification of the pyro-Cb.

The combination of heat and smoke created a cloud with extremely small drops, which ascended rapidly in violent updrafts. There appeared to be little freezing up to the homogeneous freezing isotherm level of −38°C. A cloud with such small and short-lived highly supercooled drops is incapable of producing precipitation except for few large graupel and hail, which produced the observed radar echoes and charged the cloud with positive lightning. The small cloud drops froze homogeneously to equally small ice particles, for which there is no mechanism to aggregate into precipitation particles, and which hence remain in the anvil. The lack of significant precipitation implies that only a small fraction of the smoke is scavenged, so that most of it is exhausted through the anvil to the upper troposphere and lower stratosphere.

Comparisons with other cases suggest that a pyro-Cb does not have to be as violent as the Chisholm case for precipitation to be

Firestorm Definition

- A firestorm is a conflagration which attains such intensity that it creates and sustains its own wind system. It is most commonly a natural phenomenon, created during some of the largest bushfires and wildfires. Although the term has been used to describe certain large fires, the phenomenon's determining characteristic is a fire with its own storm-force winds from every point of the compass towards the storm's center, where the air is heated and then ascends.

1. American National Fire Protection Association 2005, p. 68.
2.^ Alexander Mckee's *Dresden 1945: The Devil's Tinderbox*
3.^ *"Problems of Fire in Nuclear Warfare (1961)" (PDF). Dtic.mil. Archived from the original (PDF) on 18 February 2013. Retrieved 11 May 2016. A fire storm is characterized by strong to gale force winds blowing toward the fire everywhere around the fire perimeter and results from the rising column of hot gases over an intense, mass fire drawing in the cool air from the periphery. These winds blow the fire brands into the burning area and tend to cool the unignited fuel outside so that ignition by radiated heat is more difficult, thus limiting fire spread.*

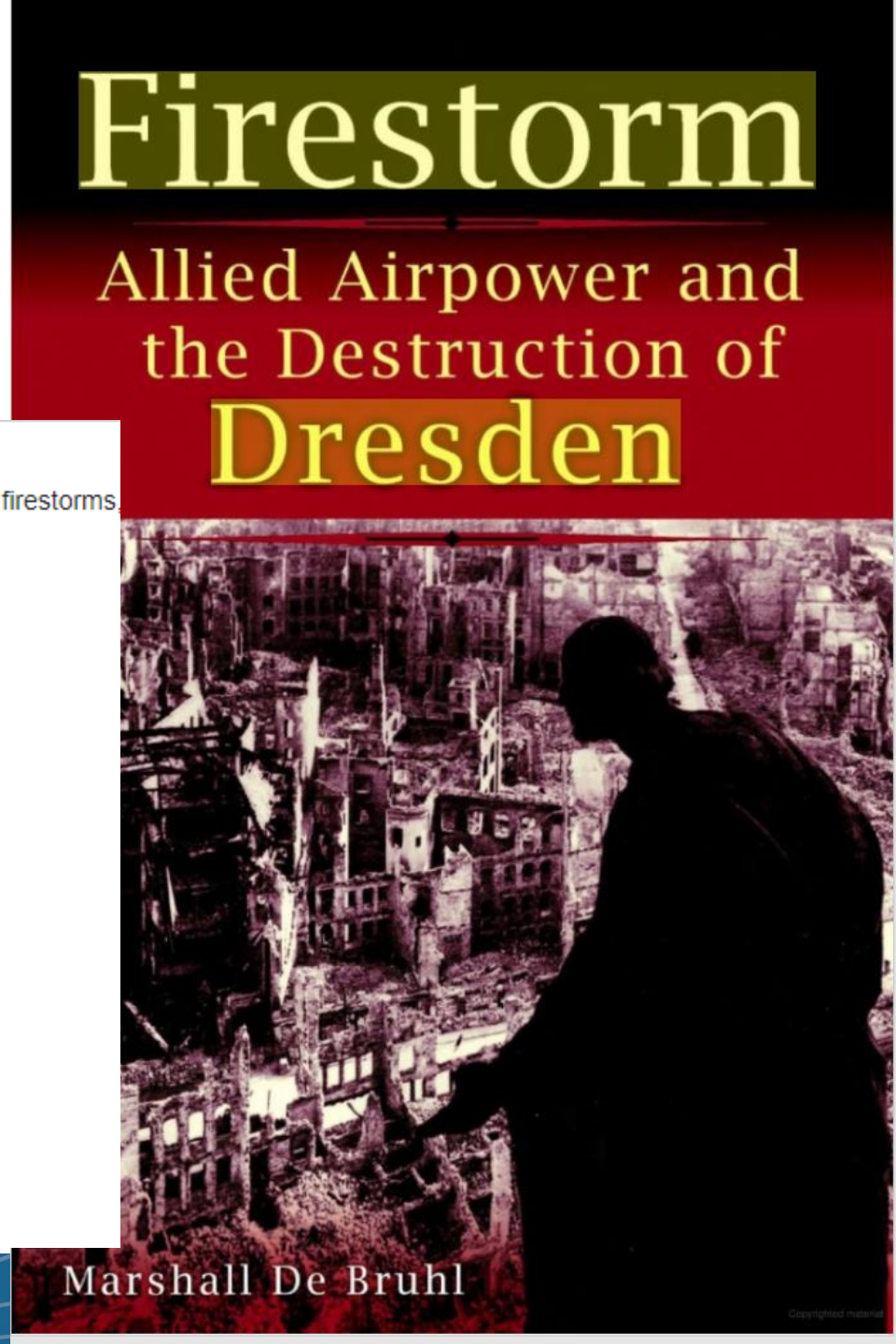
Discussion: Urban Firestorms

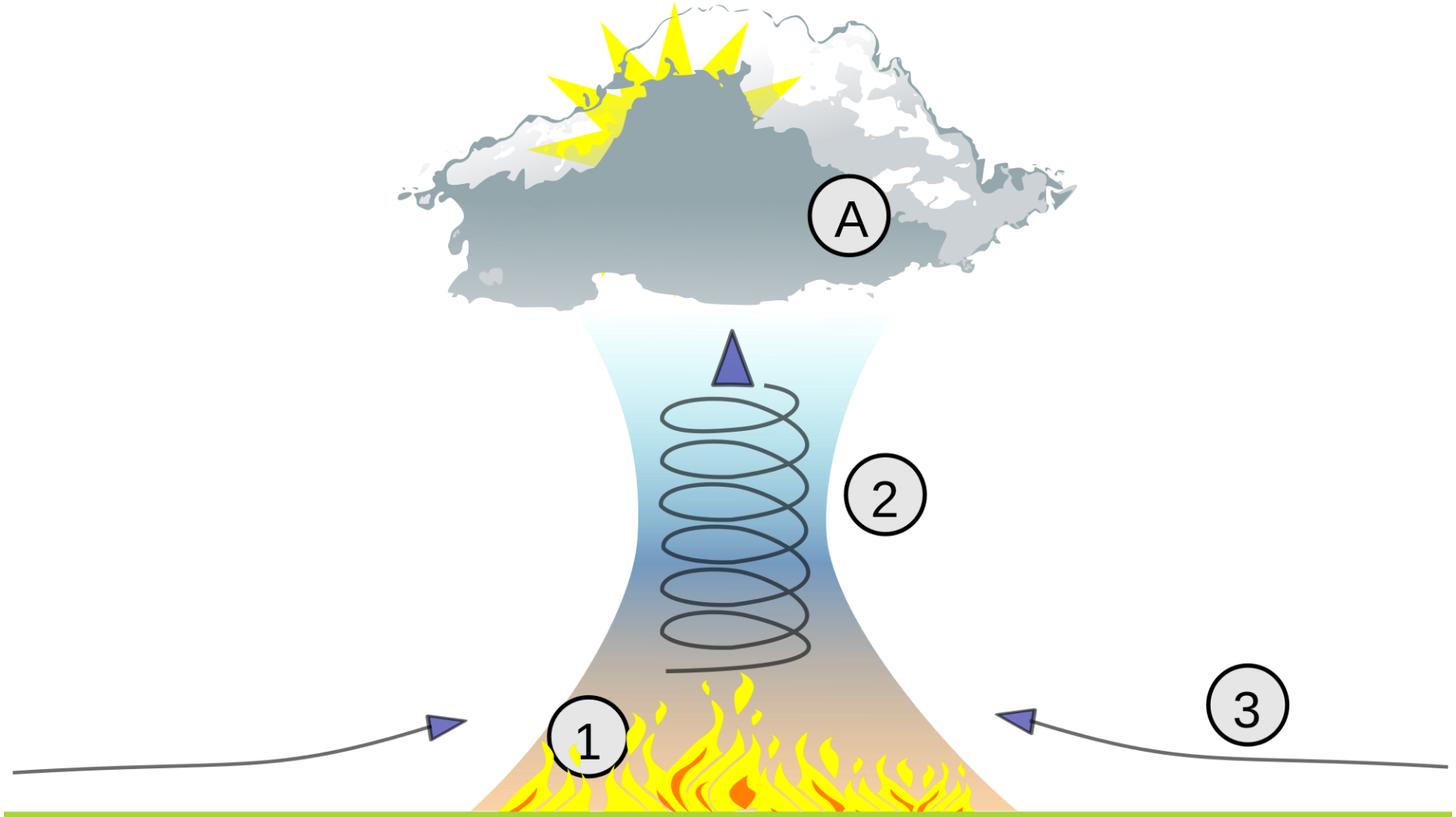
- Past notable urban firestorms
  - Great Kanto Earthquake of 1923
    - A fire whirl went through the central district
    - 38,000 people incinerated
    - Half a million structures burned
    - 1.5 million made homeless
  - World War II
    - Dresden
    - Hamburg
    - Tokyo
- Likely required conditions:
  - High fuel loads
  - Multiple fire sources
- Additional contributing conditions:
  - Surface winds not too strong?
  - Strong low-level jet
  - Helps if fuels can be mobilized by extreme winds

Potential firestorms [edit]

Portions of the following fires are often described as firestorms.

- Great Fire of Rome (64 AD)
- Great Fire of London (1666)
- Great Chicago Fire (1871)
- Peshtigo Fire (1871)
- San Francisco earthquake (1906)
- Great Kantō earthquake (1923)
- Tillamook Burn (1933–1951)
- Second Great Fire of London (1940)
- Ash Wednesday bushfires (1983)
- Yellowstone fires (1988)
- Canberra bushfires (2003)
- Okanagan Mountain Park Fire (2003)
- Black Saturday bushfires (2009)
- Fort McMurray wildfire (2016)
- Predrógão Grande wildfire (2017)
- Carr Fire (2018)



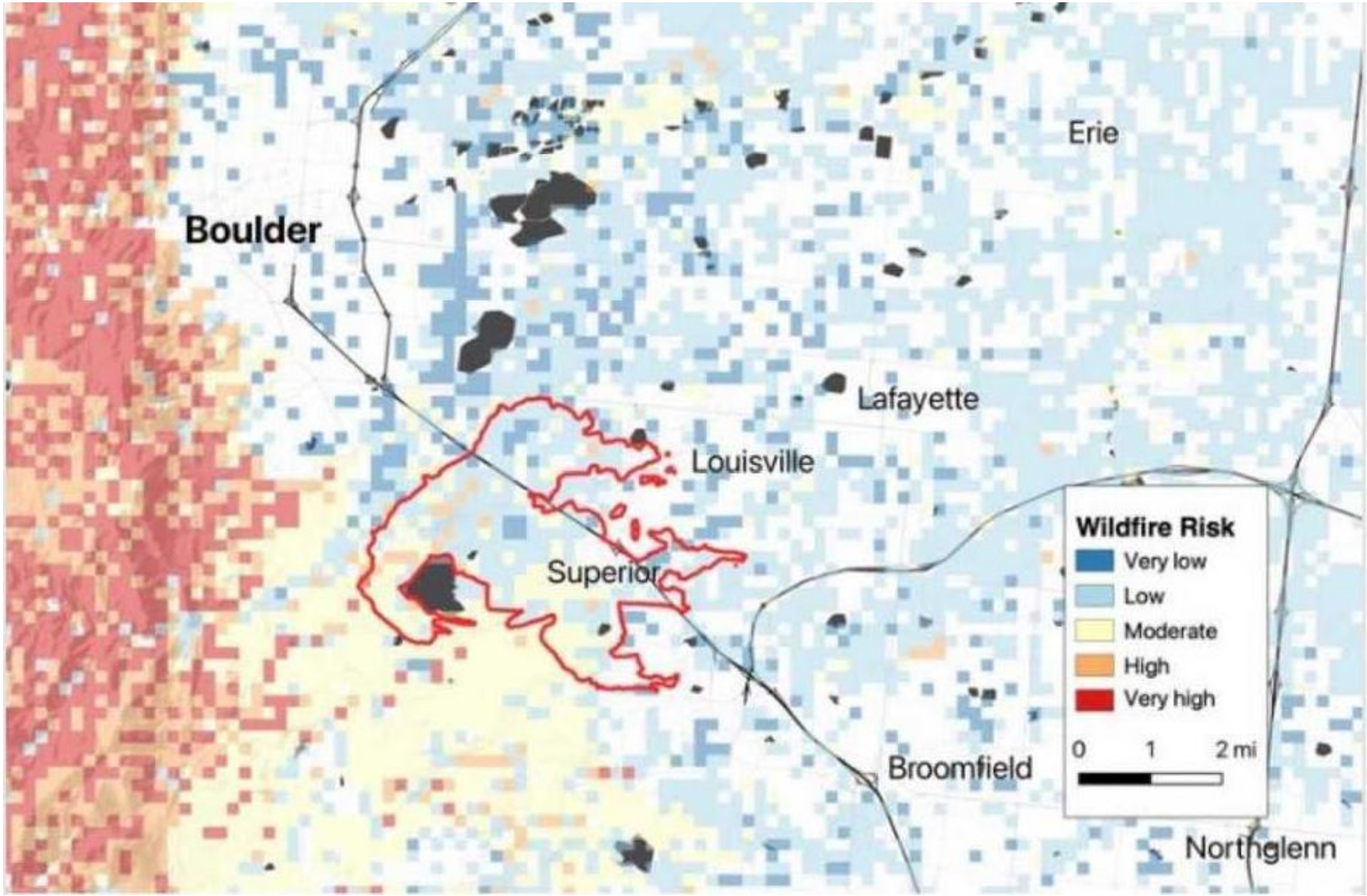


Firestorm-made thermal column. Fire (1) makes hot air (2) to rise forming storm-winds (3) towards the fires. A = Pyrocumulonimbus.

Source: https://commons.wikimedia.org/wiki/File:Firestorm_thermal_column.svg
Author: Thermal_column.svg: Dake
• derivative work: RicHard-59

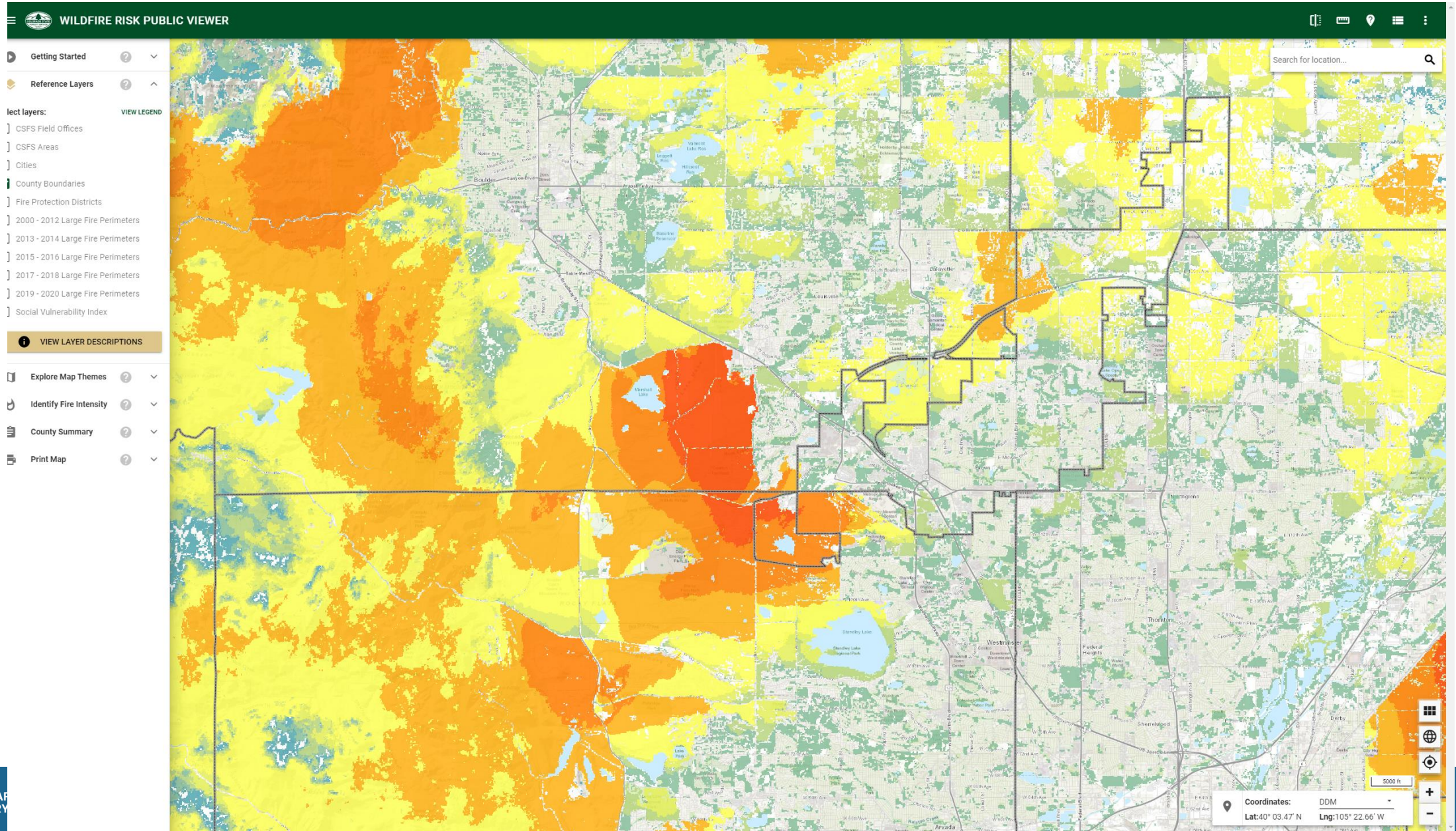
A Fire-enhanced windstorm?

- Modification of stability by the heat release from the fire



Exact source unknown: Shared on social media in the days following the fire

Potential Fire Intensity
CSU Wildfire Risk Public Viewer



Recommendations for more Fire-Wise Communities

- Require that all new construction in Louisville and Superior include fire-resistant elements
  - fire-resistant siding and roofs
  - non-flammable materials for decks
  - soffit-screens and other ember-resistant vents
  - flashing between gutters and house
  - 5 feet of space with all non-combustible materials and landscaping around each house
- Work on retrofitting existing houses as feasible
  - When siding is replaced, upgrade to fire-resistant siding
  - When a new roof is required, install ember-resistant vents
  - Give incentives for homeowners to "harden" their houses to fire.
- Keep open space and park grasses trimmed to very short levels during the windstorm season
- Replace all wooden fences with fences made from non-combustible materials
- Homeowners should maintain their properties in a fire-safe condition during the dry months
  - rake leaves
  - make sure leaves don't accumulate on roofs and gutters

Update since this talk was given

In March 2022, the National Institute for Standards and Technology (NIST) and Insurance Institute for Business and Home Safety (IBHS) released a report, entitled: “WUI Structure/Parcel/Community Fire Hazard Mitigation Methodology”

- Article about the report: https://www.nist.gov/news-events/news/2022/03/nist-offers-first-kind-guidance-holistic-home-and-community-wildfire
- Link to the report: https://nvlpubs.nist.gov/nistpubs/TechnicalNotes/NIST.TN.2205.pdf

Take home messages:

- It’s important not to skip any of the 40 aspects of wildfire resistance (a million embers hitting your house is going to find the one vulnerability).
- Resilience needs to include both structure-based mitigation and community-wide preparation.