A journey from weather to climate

Russ S. Schumacher, PhD

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COLORADO CLIMATE CENTER

GRAD592 seminar
October 2024

ATMOSPHERIC SCIENCE
COLORADO STATE UNIVERSITY

"Climate is what we expect, weather is what we get"

-- origin unclear

"Weather is like your mood, and climate is like your personality."

-- J. Marshall Shepherd

Fridley, Minnesota tornado, 18 July 1986

https://www.youtube.com/embed/SphbqvD7qSQ


National Severe
StormsLaboratory
Storm Prediction Center
313


U-HAUL
U-HAUL

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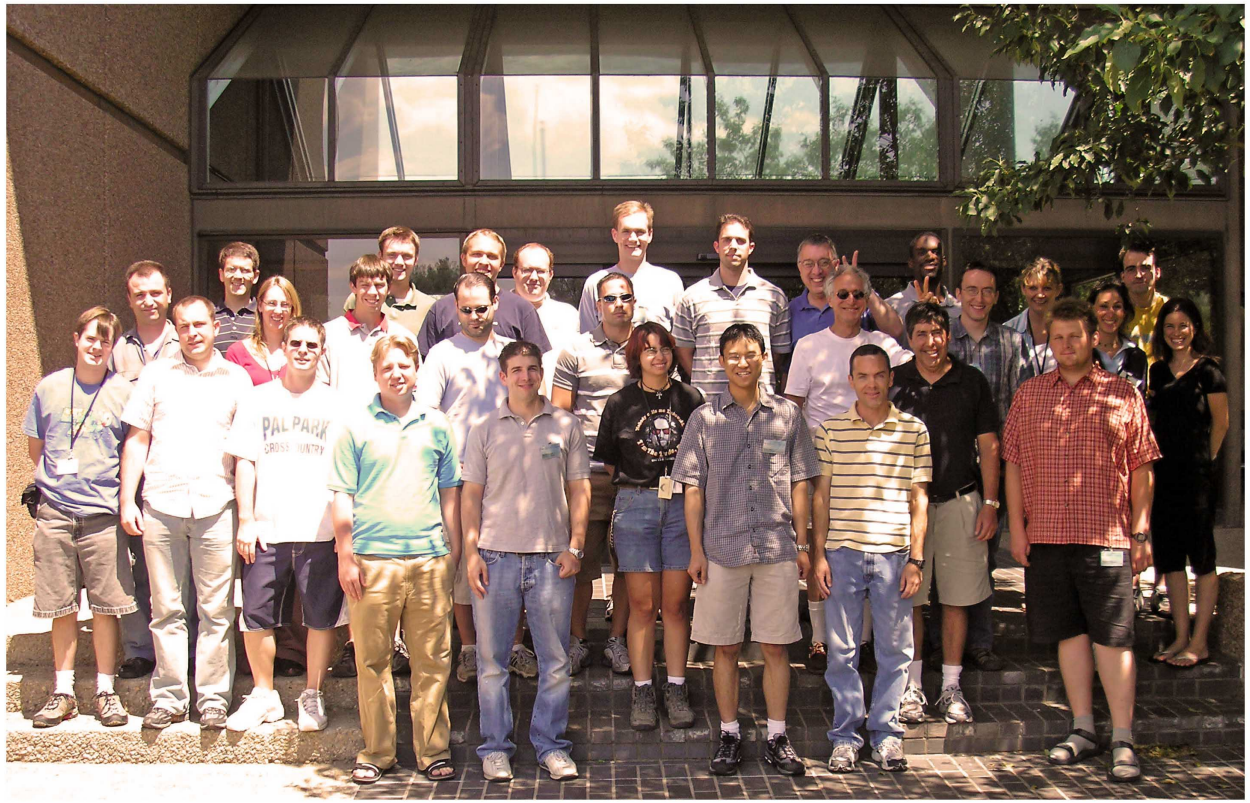
"The Challenge of Convective Forecasting"
National Center for Atmospheric Research, July 2006



Weather and Society: Integrated Studies (WAS*IS)
Summer 2007

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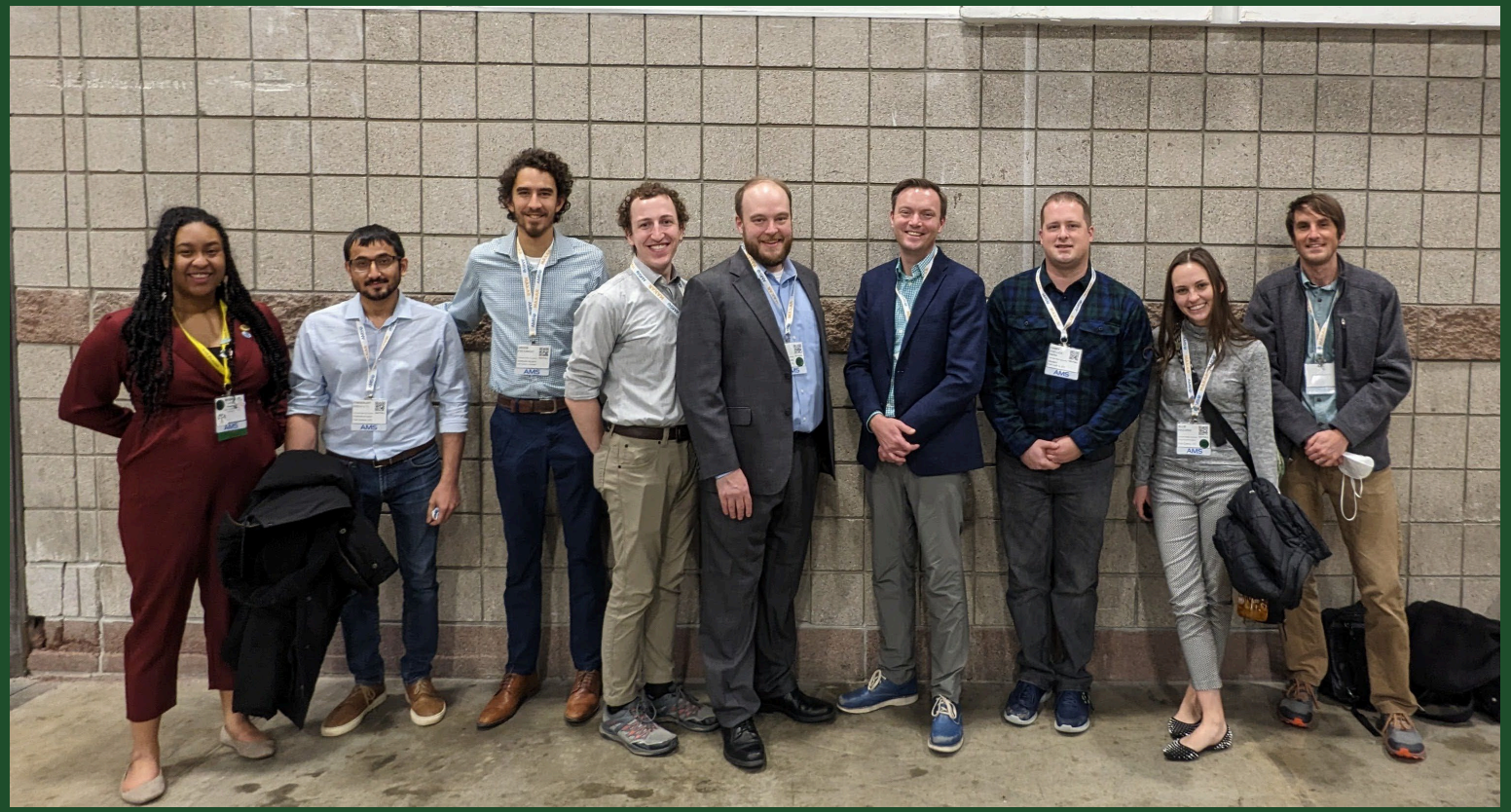
My research

Advancing understanding and prediction of high-impact weather, especially extreme precipitation

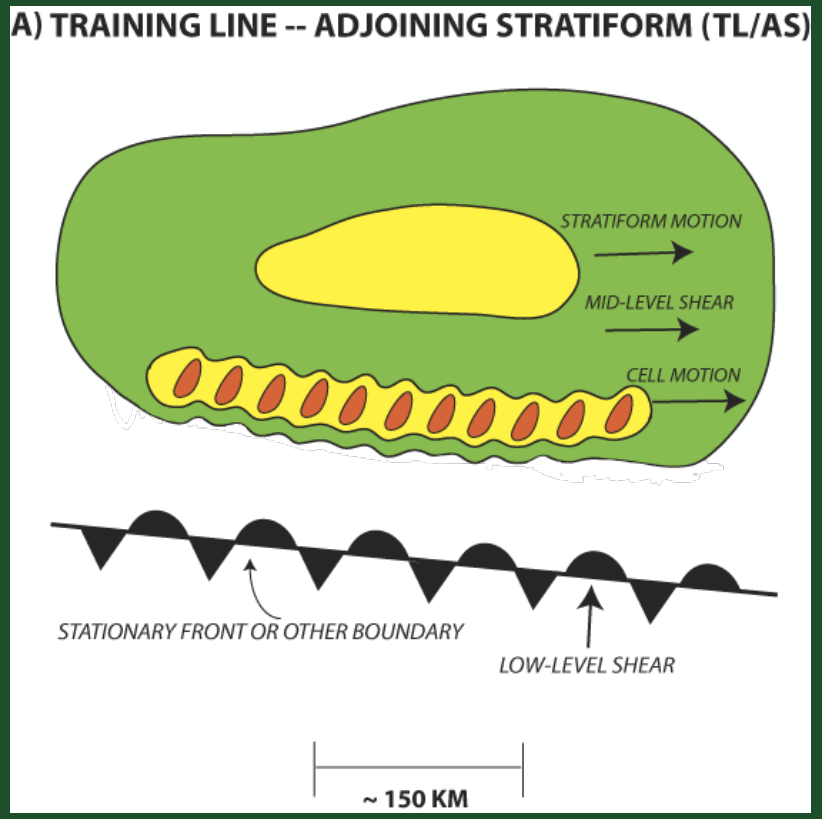


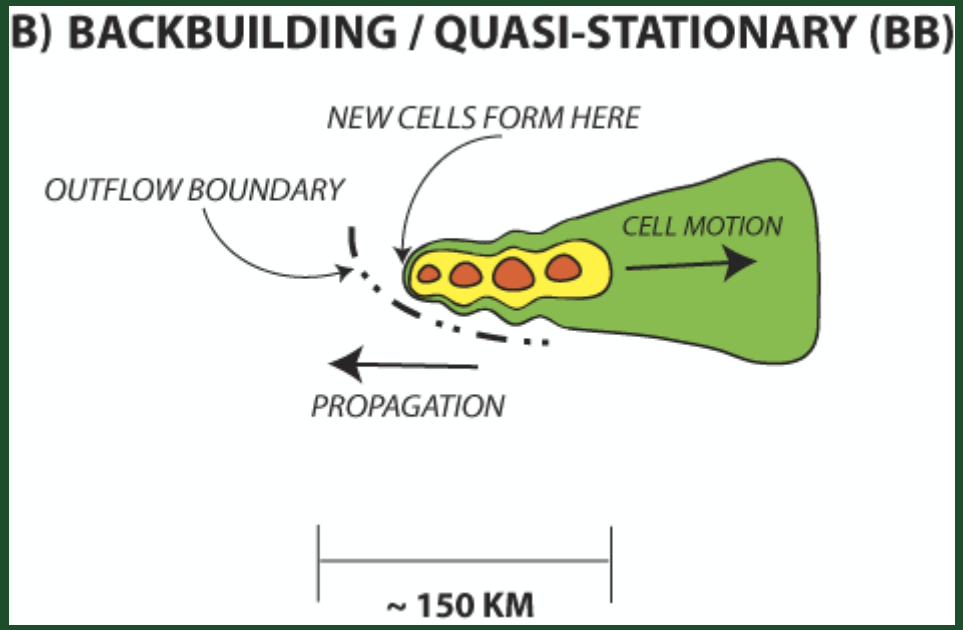
Research group, January 2023

Extreme rainfall

Simply: $P = \overline{R}D$ (precipitation equals average rainfall rate times duration)

- In other words, the most rain falls where it rains the hardest for the longest!
- What kinds of storms maximize R and D?



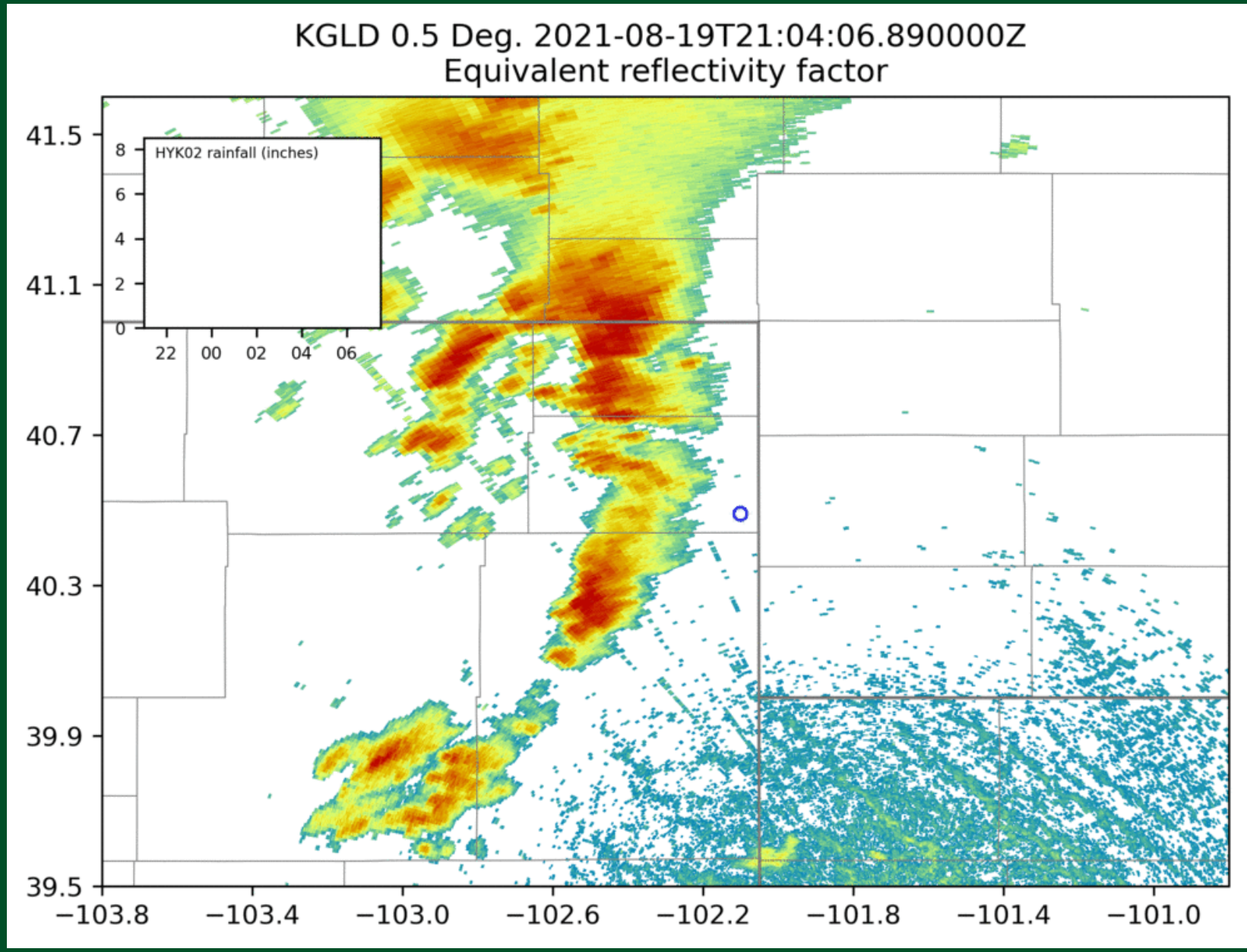


(Schumacher and Johnson 2005; see also Schumacher 2017 in Oxford Encyclopedia of Natural Hazards Science)

August 19, 2021 rainstorm

At Holyoke COOP station, 4.26” (2nd wettest day on record)

At Holyoke CoAgMET station, 8.04”



Floods are by nature an interdisciplinary problem!

- What happens in the atmosphere to get the rain to the ground? (meteorology)
- What happens to the water once it hits the ground? (hydrology)
- What impacts does the flooding have on people? (sociology, economics, emergency management, etc., etc.)
- What impacts does the flooding have on ecosystems? (ecology, etc.)
- How will floods change in the future? (climate, floodplain management, policy)

SPREAD workshop, June 2013

Statistician describing extreme value theory to hydrologists, historians, and meteorologists

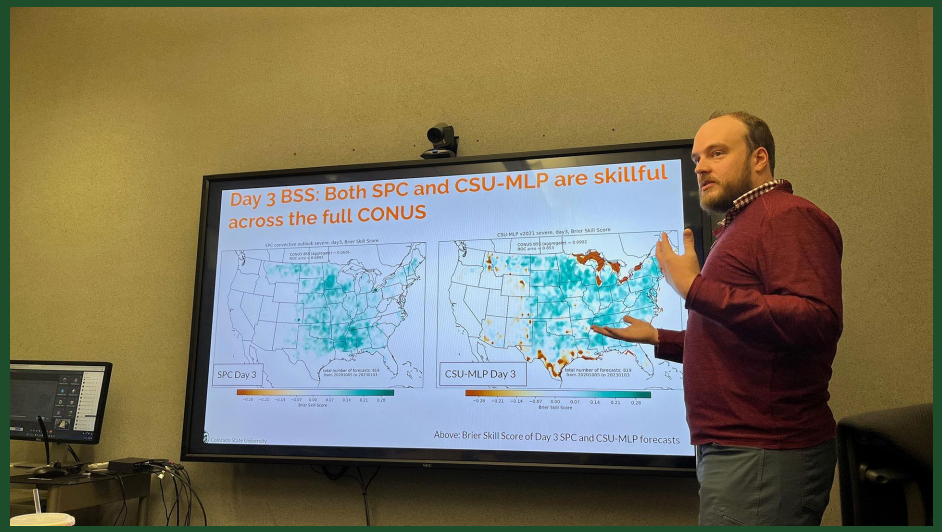
COLORADO STATE UNIVERSITY | WALTER SCOTT, JR. COLLEGE OF ENGINEERING

College News | CSU Magazines | Latest Headlines | Students | Research | Events | Engineering C

CSU machine learning model helps forecasters improve confidence in storm prediction

26 Feb, 2023
By Anne Manning

When severe weather is brewing and life-threatening hazards like heavy rain, hail or tornadoes are possible, advance warning and accurate predictions are of utmost importance. Colorado State University weather researchers have given storm forecasters a powerful new tool to improve confidence in their forecasts and potentially save lives.



[ATS 780A8]

Weather-to-Climate Data Driven Forecasting

What/Why: Data-driven approaches (e.g. machine learning) for forecasting are proving to be incredibly powerful – transforming prediction science. This course covers the scientific basis for data-driven forecasting methods from days-to-decades and explains how these methods are applied and evaluated for use in research and forecasting of Earth system processes (e.g. weather, climate, air quality, wildfires). Throughout the course, students will design, build, analyze and evaluate their own data-driven prediction systems.

When: M / W 0900-1015; Fall 2024

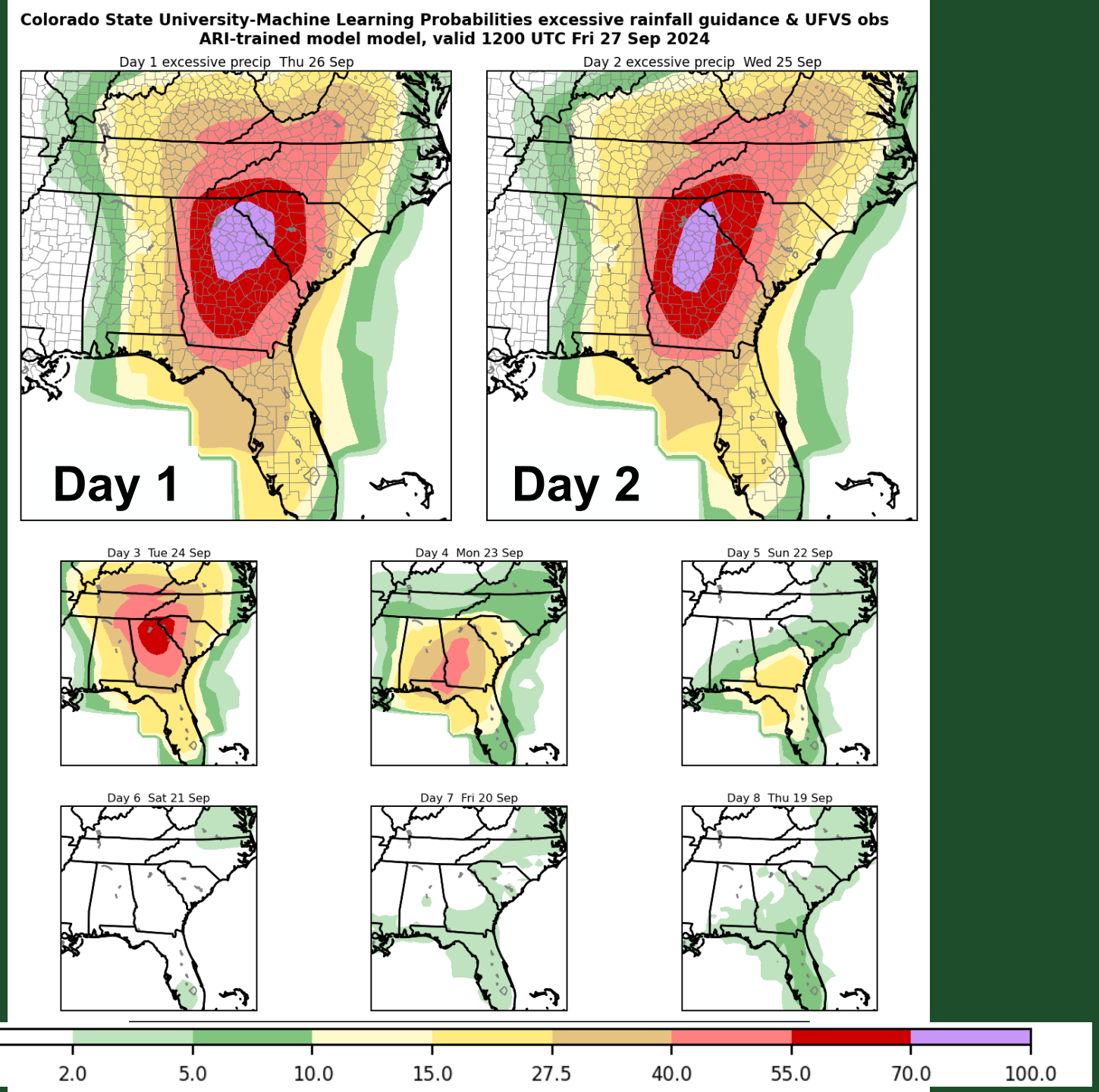
Who: Co-Taught by Prof. Elizabeth Barnes and Prof. Russ Schumacher

Where: ATS 101 Main Building on the CSU Foothills Campus

CSU-MLP excessive rainfall probabilities

Helene (2024)

Real-time forecast graphics:



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CSU-MLP excessive rainfall probabilities

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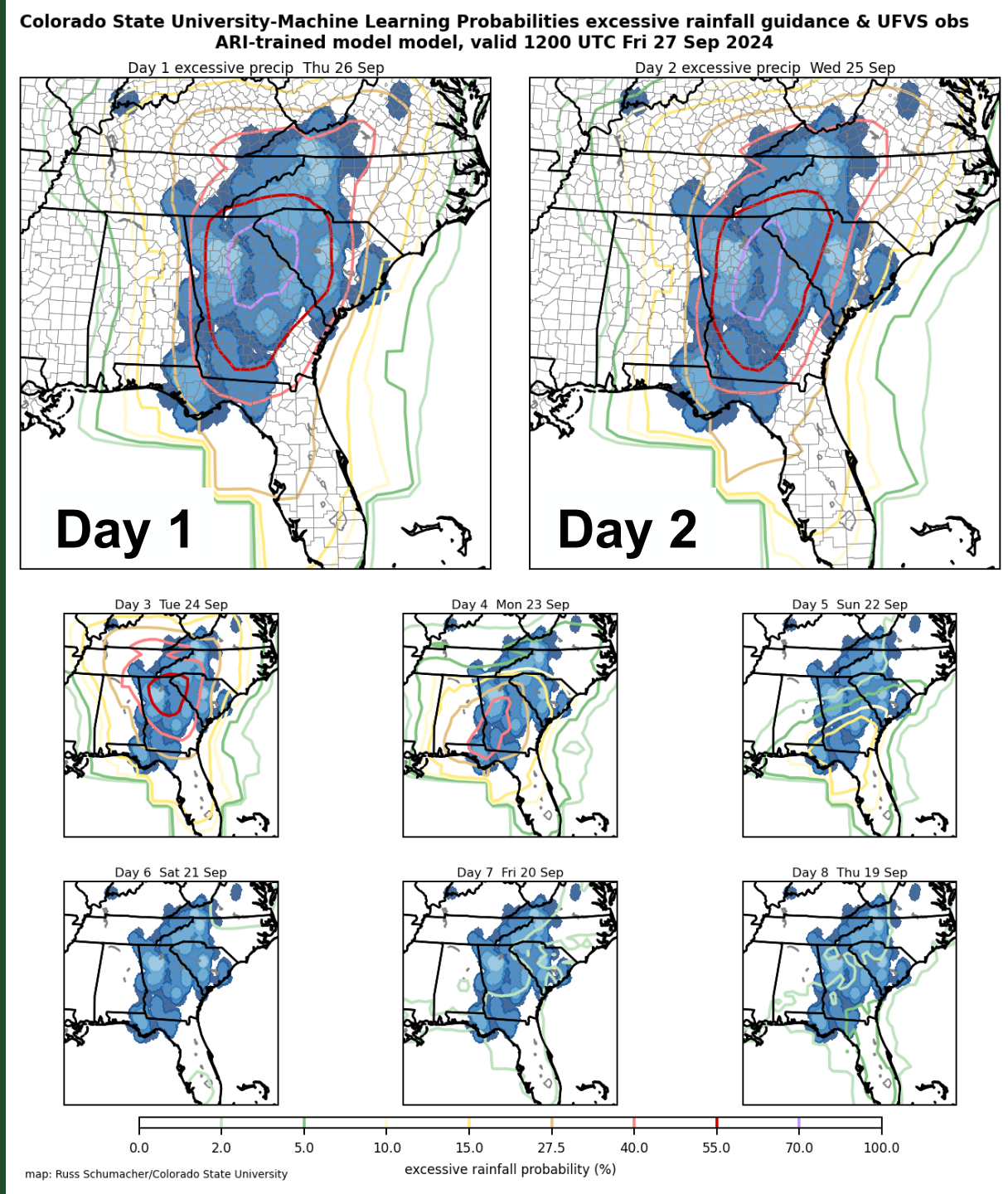
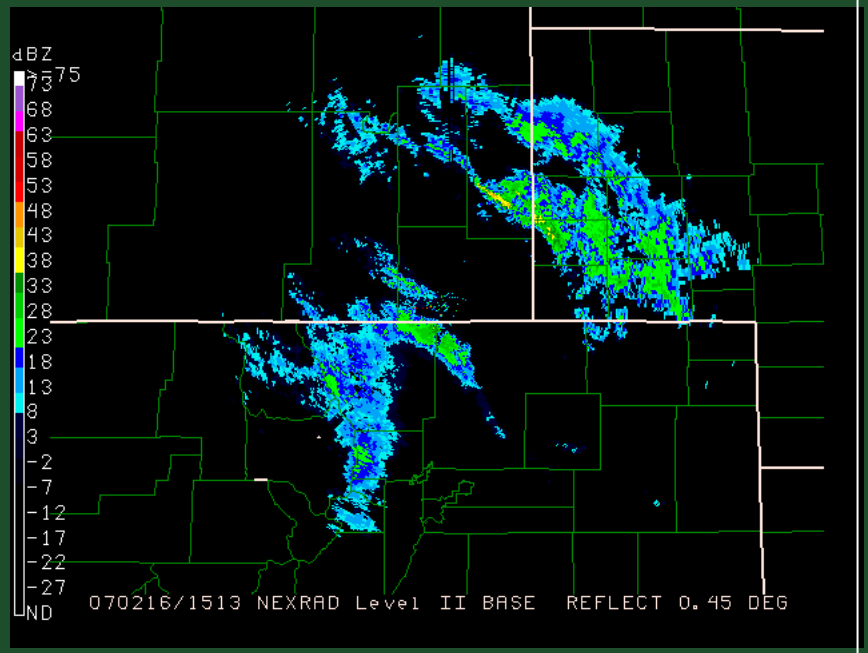
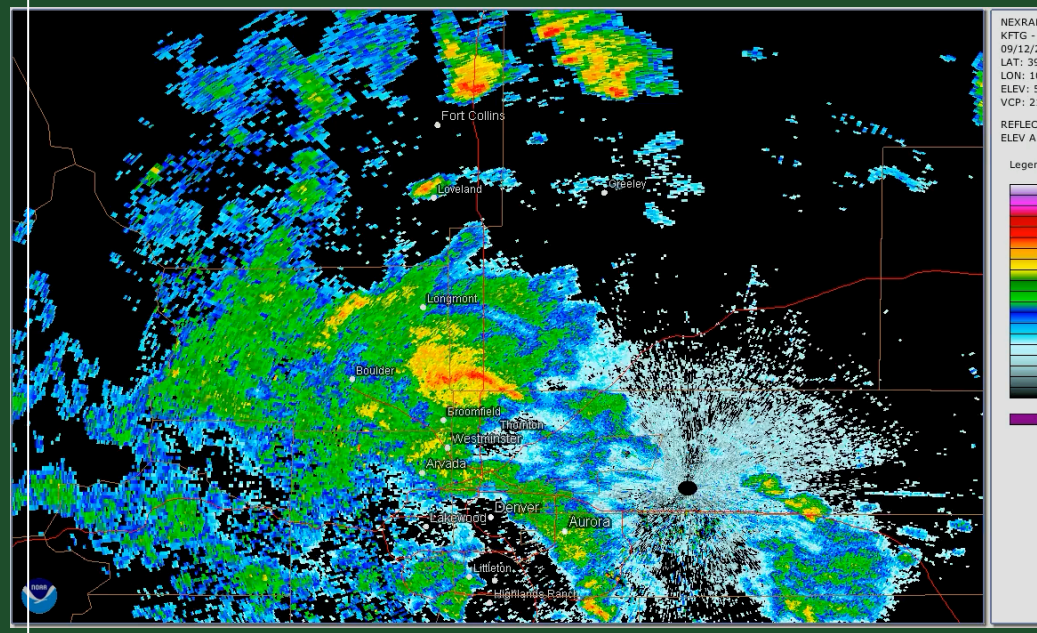
Real-time forecast graphics:



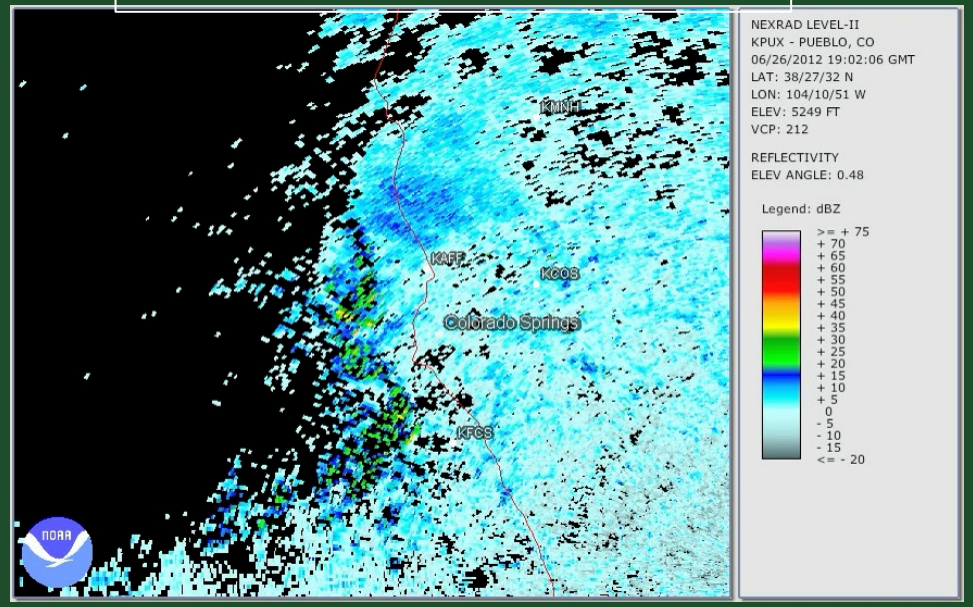
My advisor (Dick Johnson) encouraged his students to pursue their own ideas, and I followed his lead in carefully analyzing Colorado's high-impact mesoscale weather…



16 February 2007 banded heavy snowfall
Schumacher et al. (2010, 2015)



The Great Colorado Flood of September 2013
Gochis et al. (2015); Morales et al. (2015)



26 June 2012 Waldo Canyon Fire
Johnson et al. (2014)

EF-3 tornado, Weld County, CO
22 May 2008

Multidisciplinary Analysis of an Unusual Tornado: Meteorology, Climatology, and the Communication and Interpretation of Warnings*

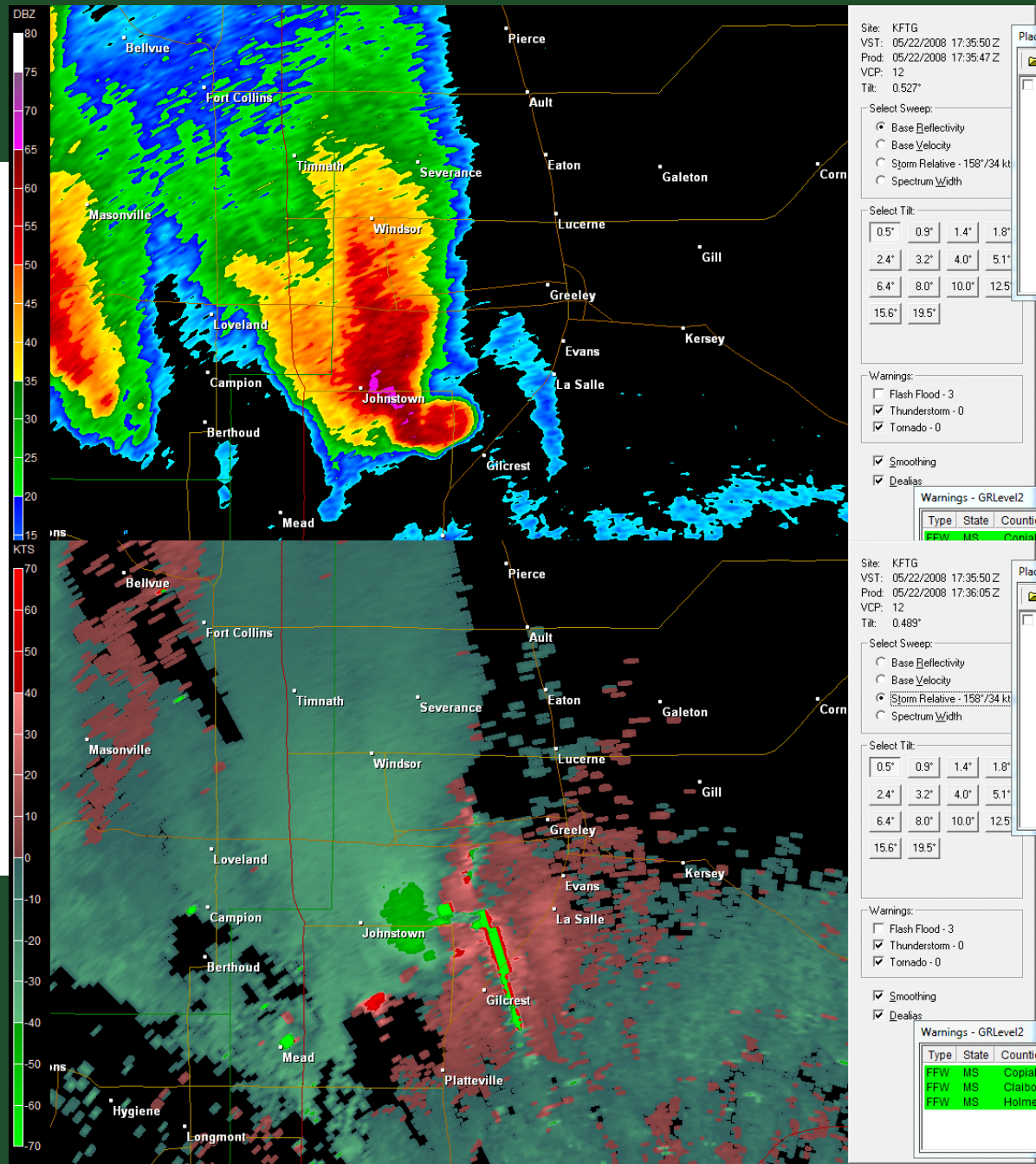
RUSS S. SCHUMACHER+
National Center for Atmospheric Research,# Boulder, Colorado

DANIEL T. LINDSEY
NOAA/NESDIS/STAR/RAMMB, Fort Collins, Colorado

ANDREA B. SCHUMACHER, JEFF BRAUN, AND STEVEN D. MILLER
Cooperative Institute for Research in the Atmosphere, Colorado State University, Fort Collins, Colorado

JULIE L. DEMUTH
National Center for Atmospheric Research,# Boulder, Colorado

(Manuscript received 28 December 2009, in final form 9 April 2010)



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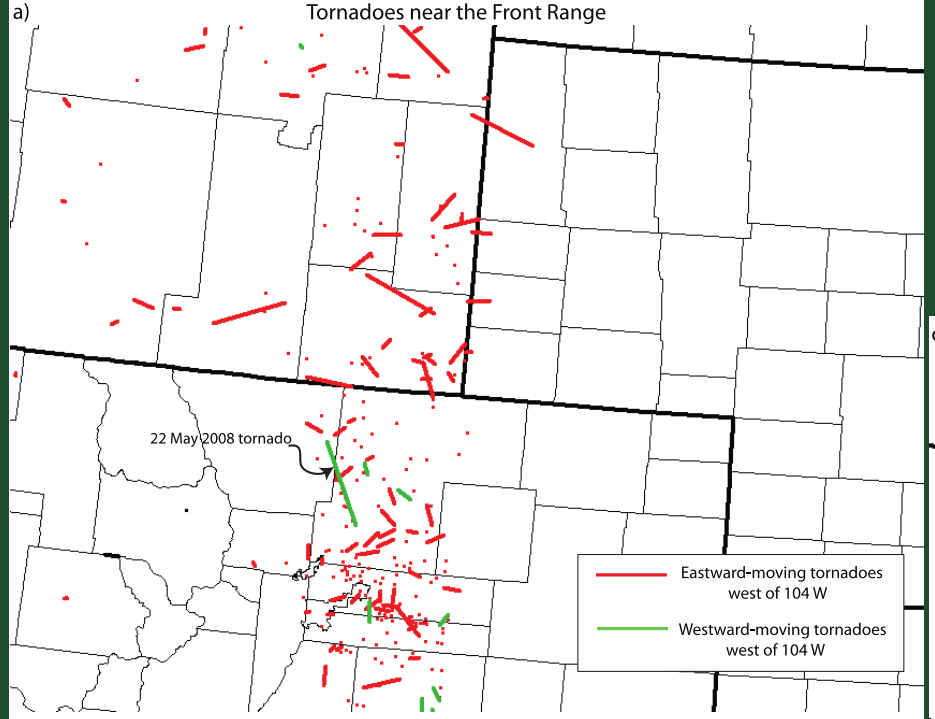
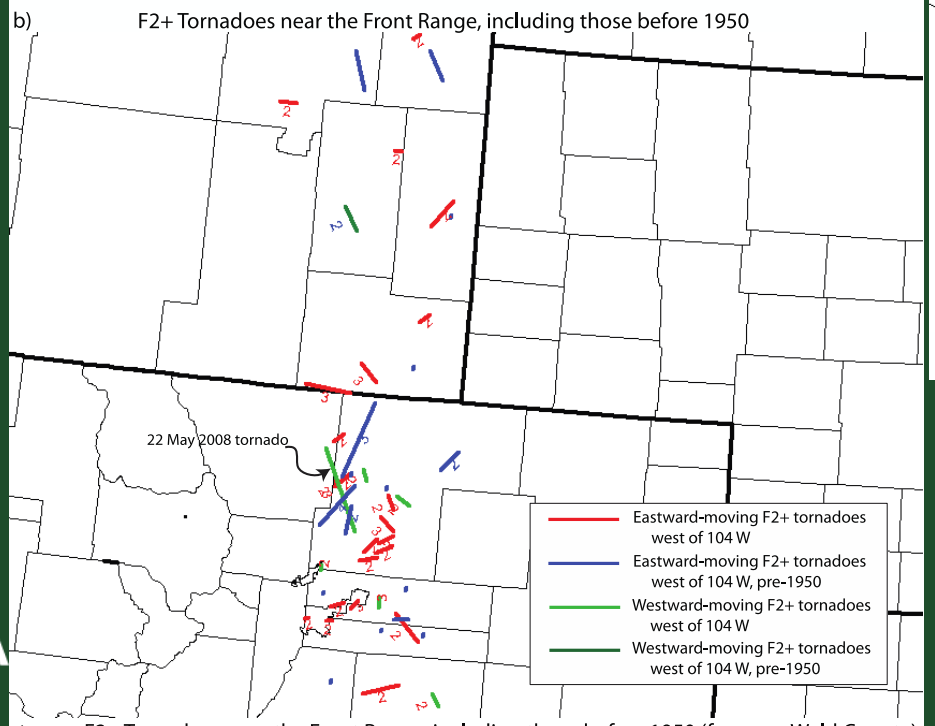
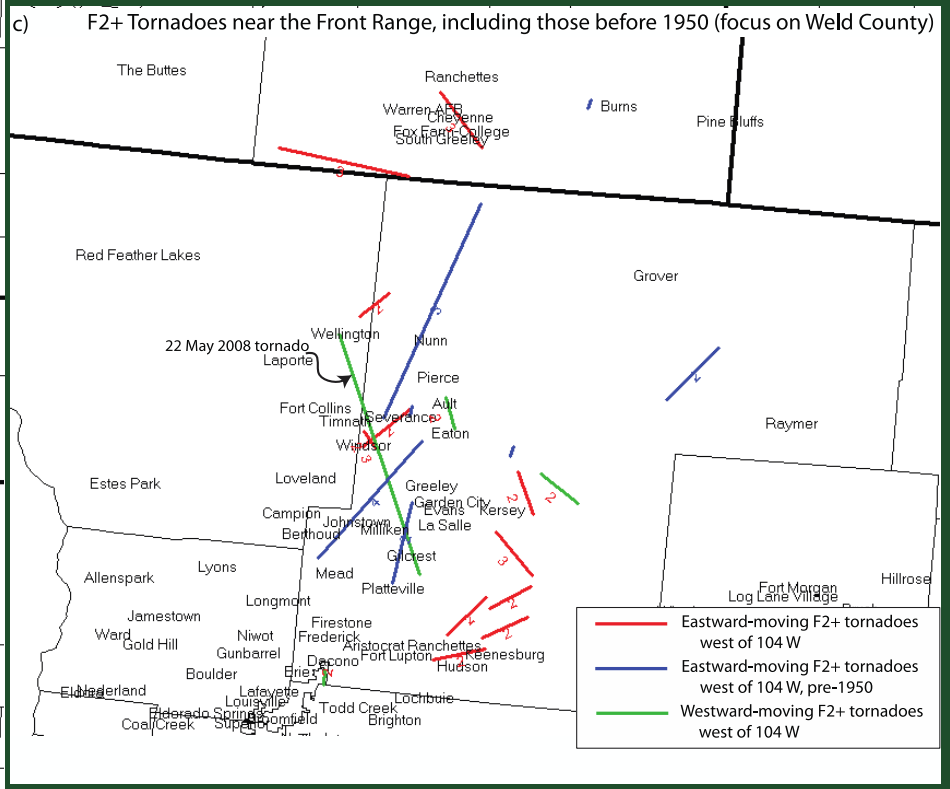




← All tornadoes near Front Range, 1950-2008

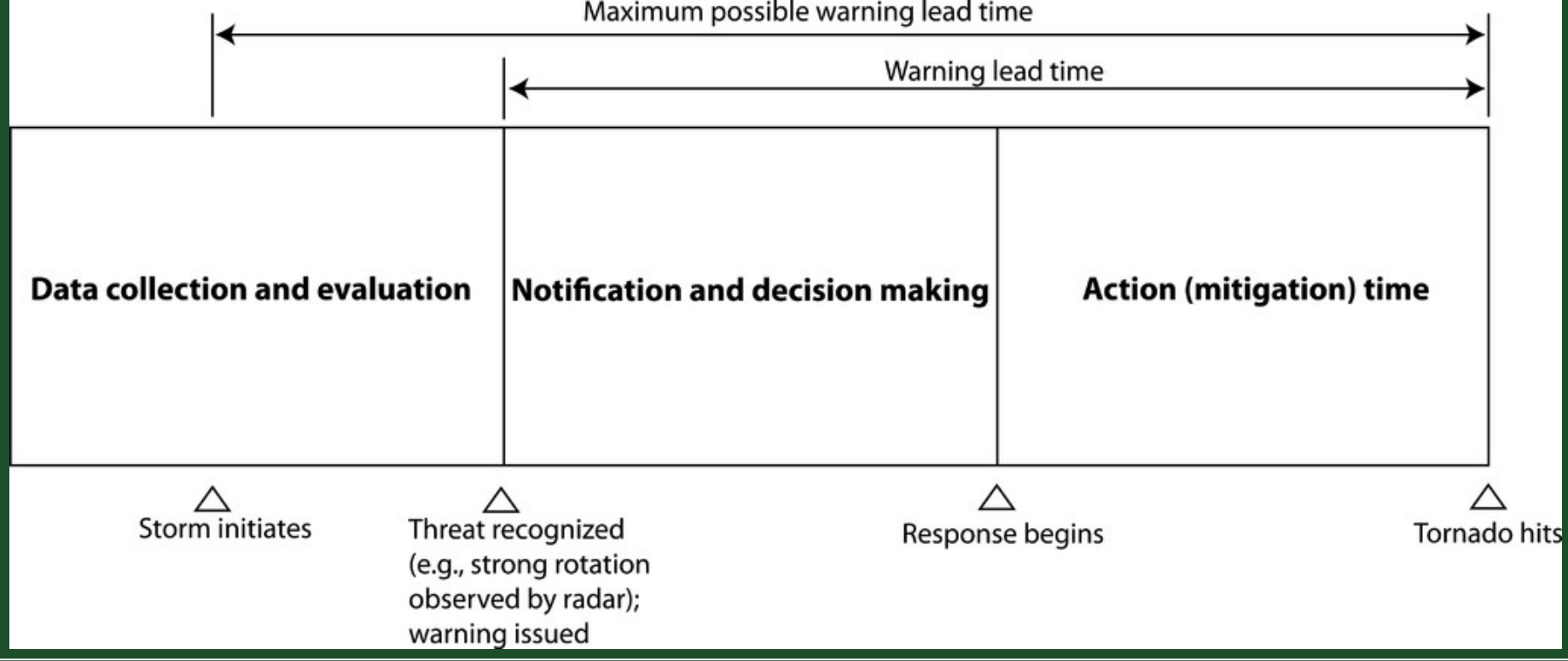
Zoom in



← F2+ tornadoes near Front Range

Schumacher et al. (2010)

COLORA



"In contrast, the second official either did not hear or disregarded the information about the northward motion of the storm; this person thought that since tornadoes generally move toward the east, that there was not an immediate threat to their area of responsibility. This person did not hear another warning until just a few minutes before the tornado hit, even though warnings and severe weather statements were being issued throughout this time."

Schumacher et al. (2010)

Nolan Doesken: 40 years of service to Colorado

30 years as assistant state climatologist; 10 years as SC

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Brief history of the Colorado Climate Center

- Until 1973, the federal government operated a “state climatologist” program – but in in 1973 this was abolished
- Later that same year, Colorado established the Colorado Climate Center at CSU with support through the Colorado Agricultural Experiment Station

The Colorado Climate Center at CSU provides valuable climate expertise to the residents of the state through its threefold program of:

1) ***Climate Monitoring*** (data acquisition, analysis, and archiving)

2) ***Climate Research***

3) ***Climate Services*** (providing data, analysis, climate expertise, education and outreach)

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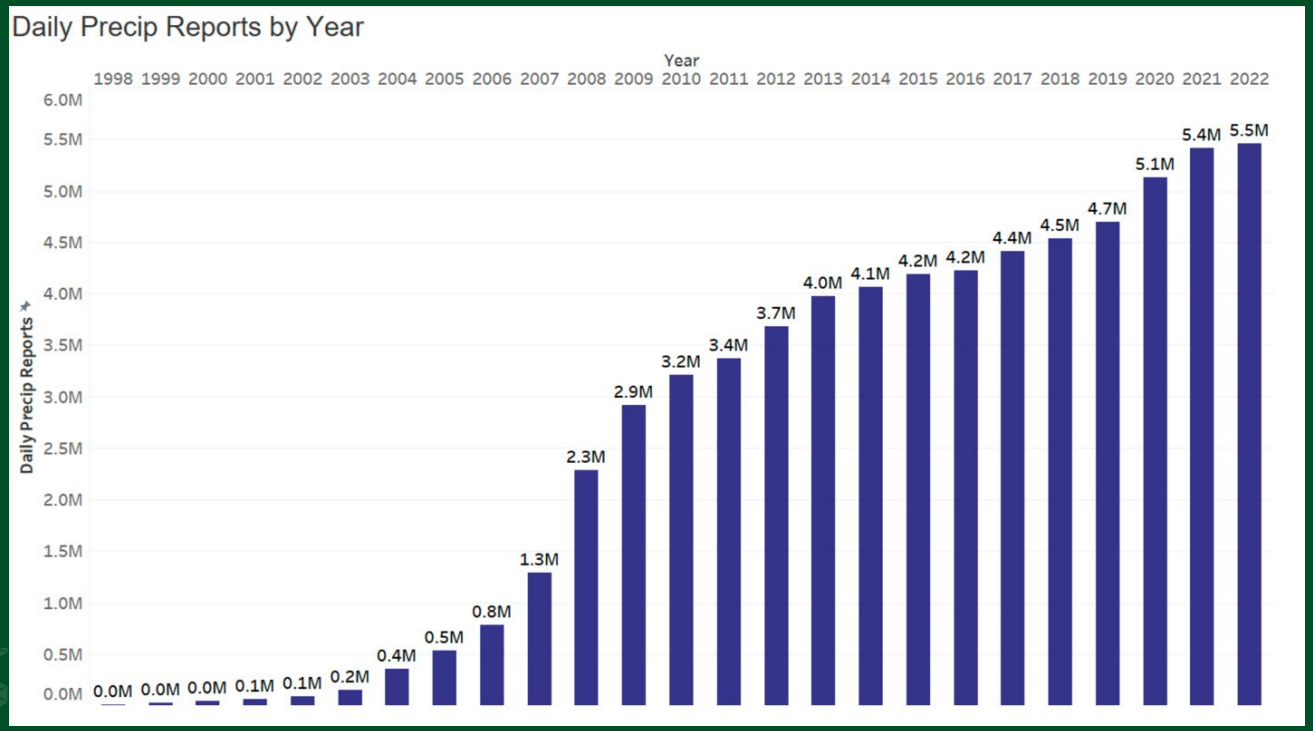
The Community Collaborative Rain, Hail and Snow Network

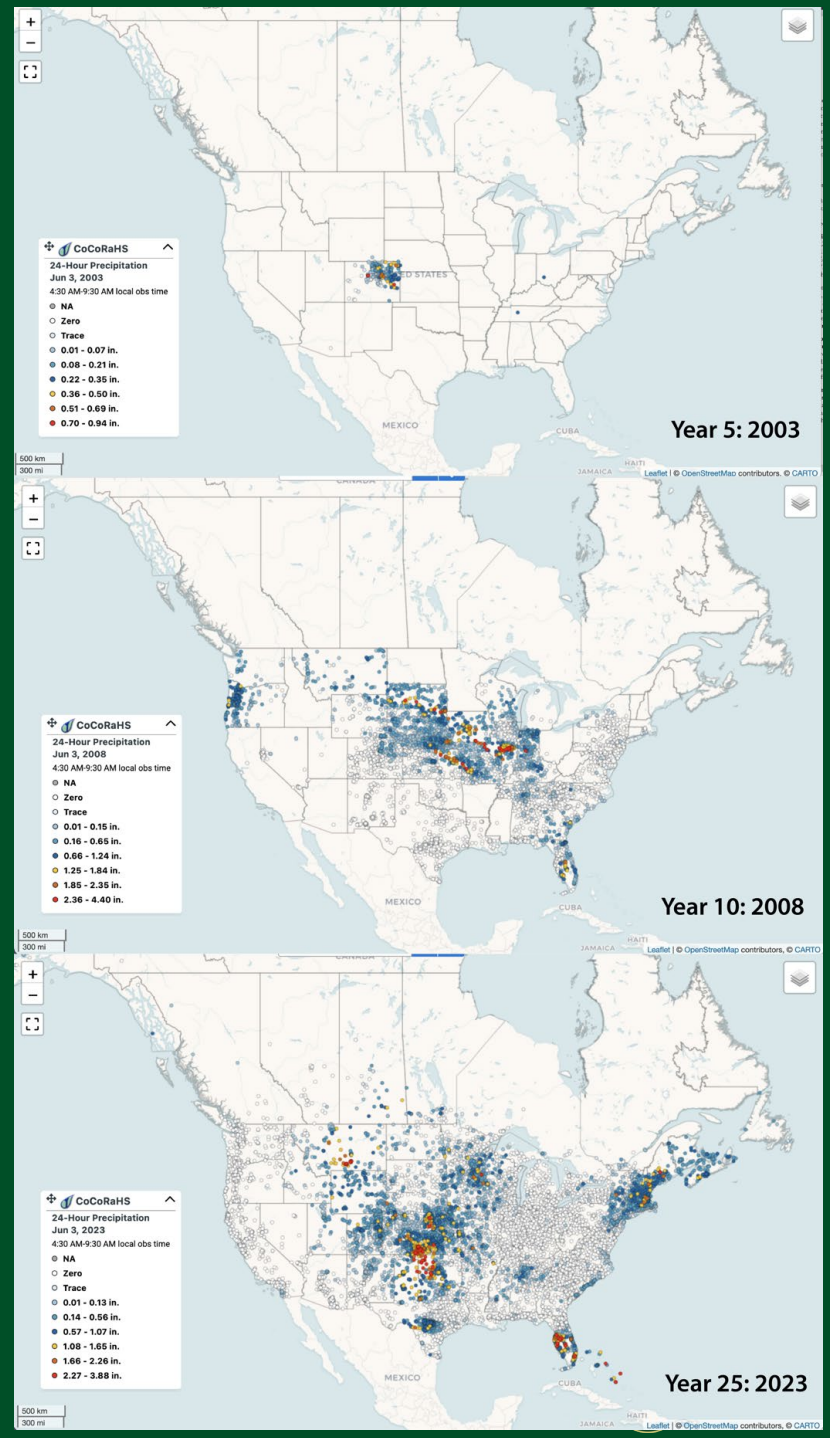
https://www.cocorahs.org

CoCoRaHS was born in response to the 1997 Fort Collins, Colorado Flood

CoCoRaHS celebrates 25 years!

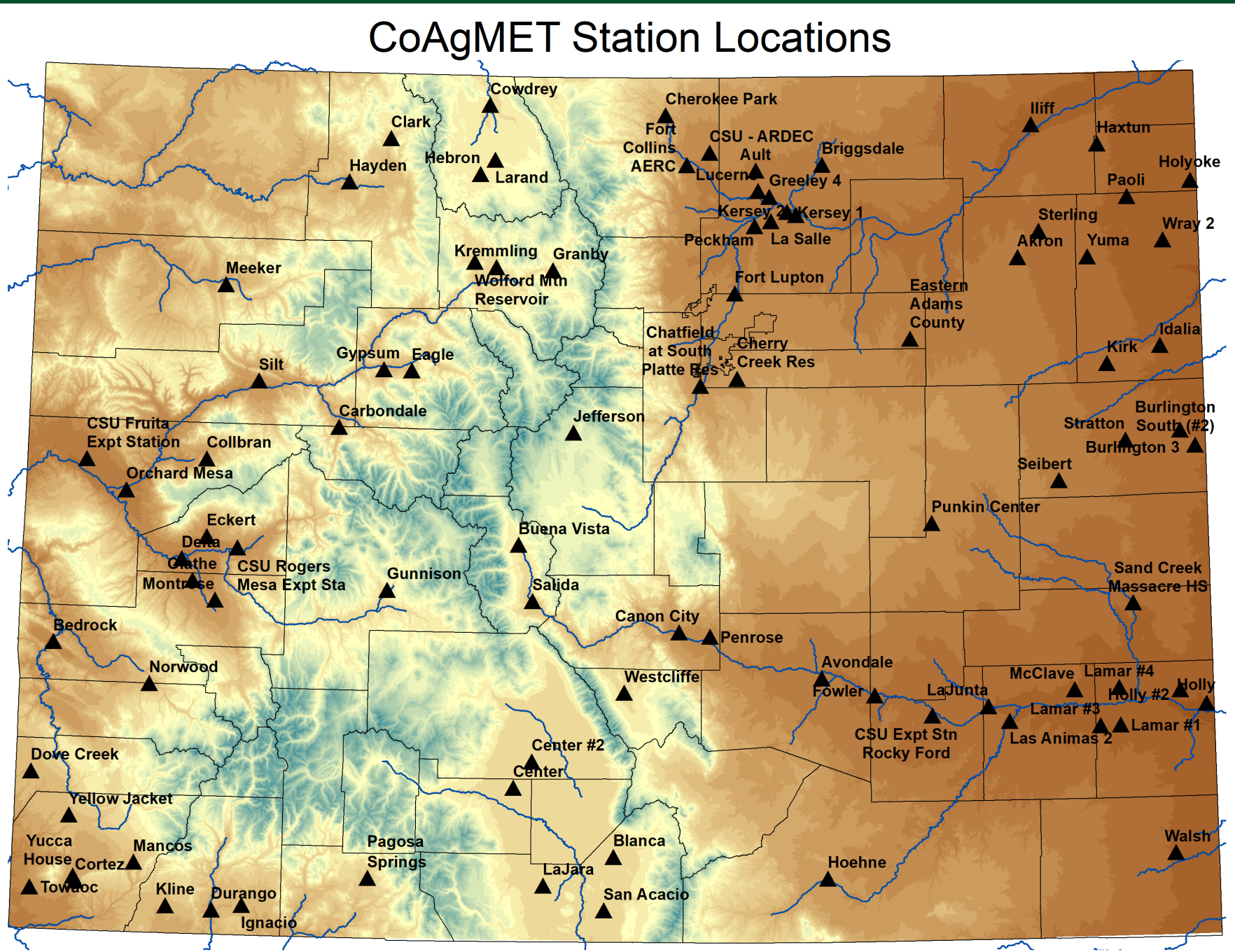
In NOAA's daily precipitation dataset, 2/3 of the observations in 2022 came from CoCoRaHS observers!



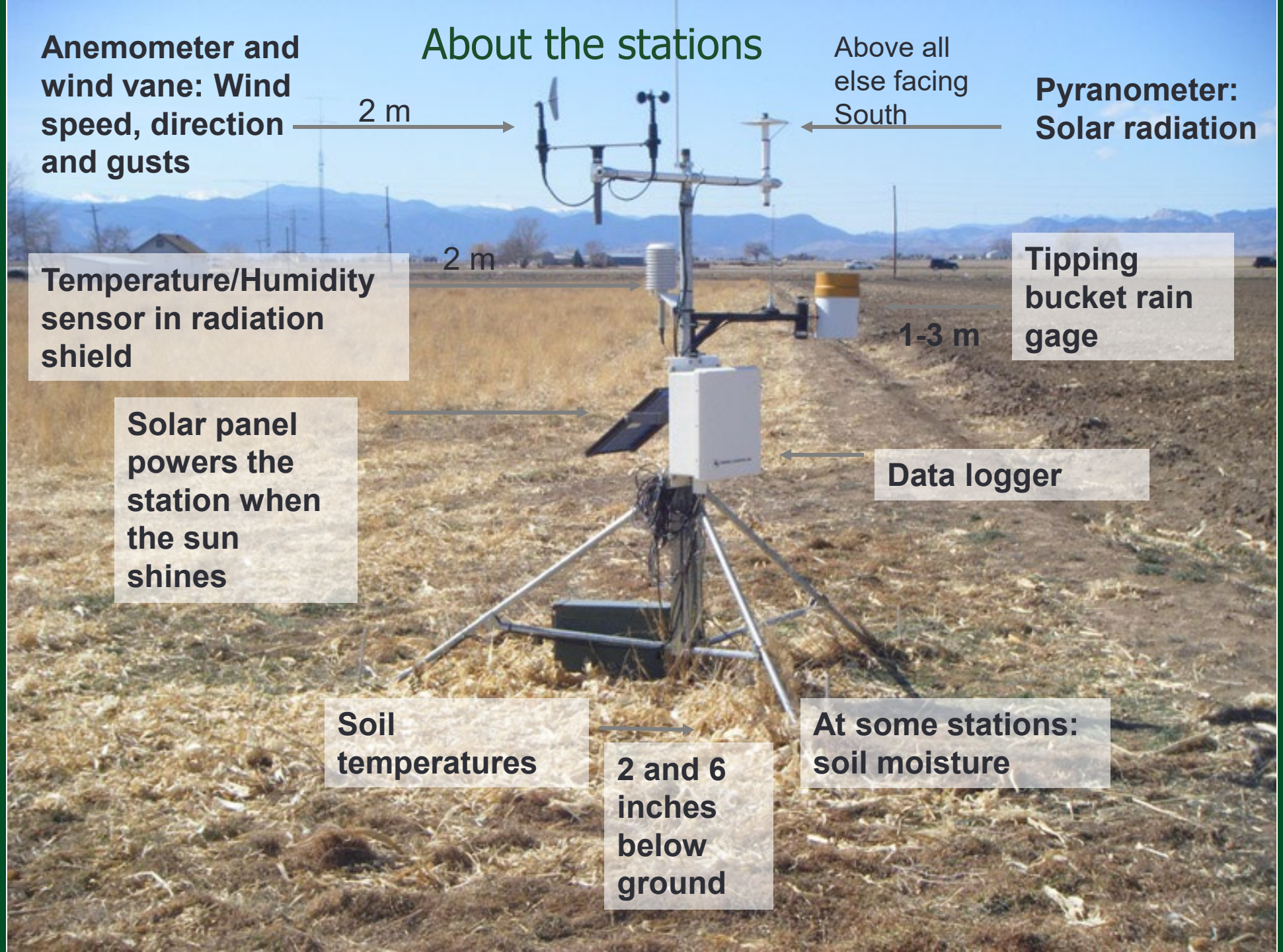


Colorado Agricultural Meteorological Network (CoAgMET), aka "Colorado's Mesonet"

Funding sources: National Mesonet Program, CWCB, station sponsors, Reclamation, Northern Water



About the stations



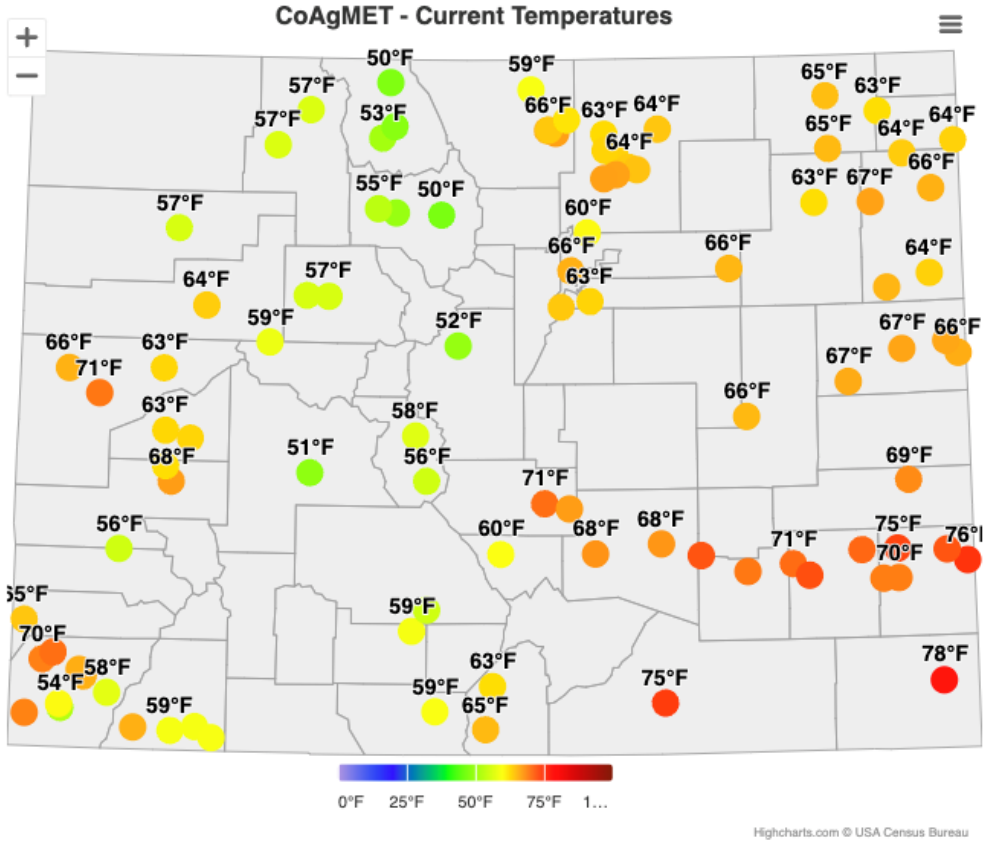
New website, just released!

coagmet.colostate.edu

COLORADO STATE UNIVERSITY | COLORADO CLIMATE CENTER | CoAgMET

CoAgMET | About | Daily Maps | Ag Weather Conditions | Data Access | Graphs & Summaries

quick access: yesterday's summary | surface map | station pages



Fort Collins AERC

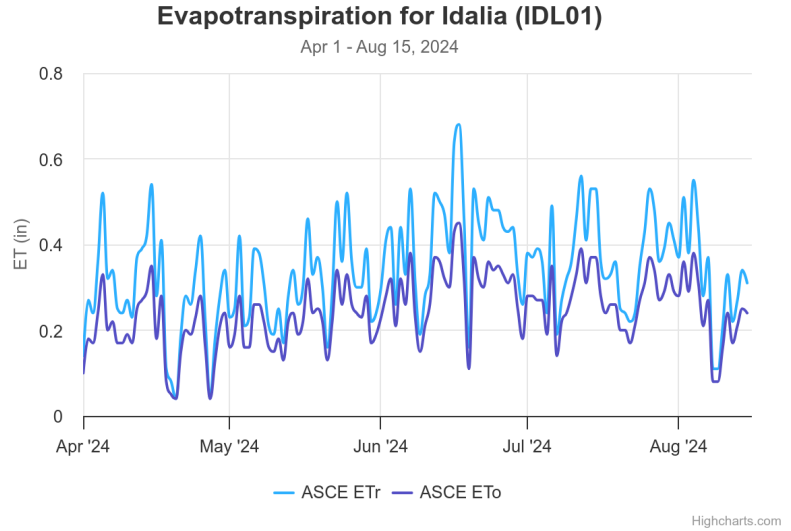
Fort Collins AERC

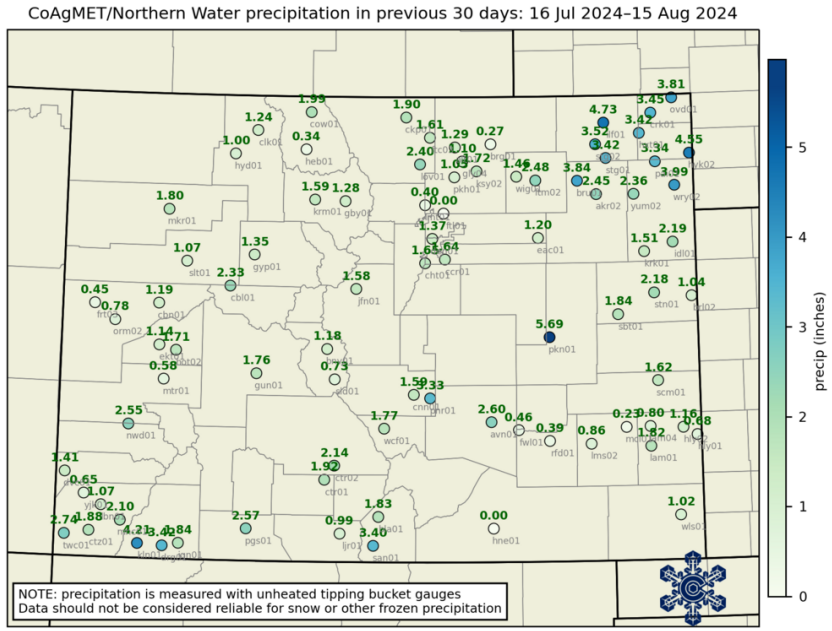
Observation Time:
Aug 16, 2024 8:15AM MDT

Temp/Dewpt: 64.3°F / 55.7°F
Rel. Humidity: 74%
Winds: Calm

go to the ftc01 station page
view ftc01 weather graphs

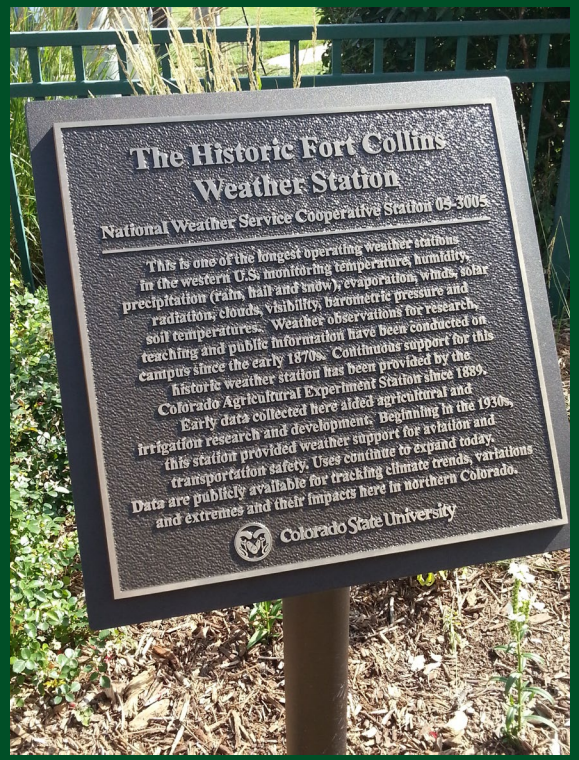
air temperature | dewpoint | relative humidity





The Historic Fort Collins Weather Station

First established in 1872, on the CSU campus since 1879, consistent data since 1889
At current location since 1961



Station Locations

1	R. Q. Tenney's Farm (1872-1874)
2	South of Old Main (1879-1885?)
3	Between Old Main and The Oval (1887-1910)
4	Civil Engineering Bldg. SW of the Oval (1911-1939)
5	The Lagoon (1940-1961)
6	Current position (May 15th, 1961- present)

Nolan Doesken discussing the history of the station:
https://www.youtube.com/watch?v=c-Za8TPTvlc

Drought monitoring and analysis

https://climate.colostate.edu/drought/

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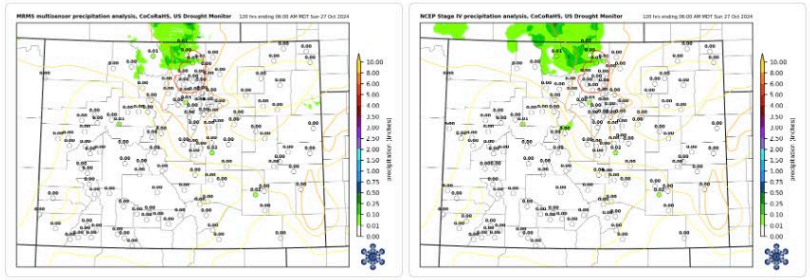
- Home
- Precipitation
- Snowpack
- Temperature
- Soil & Vegetation
- Evaporative Demand
- Streamflow
- Reservoirs
- Outlook
- US Drought Monitor

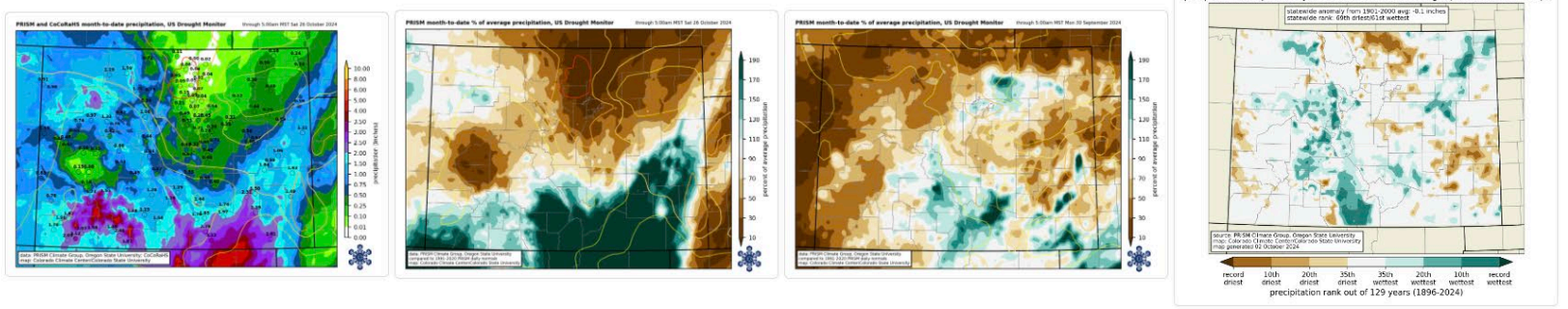
Colorado Drought Update

precipitation

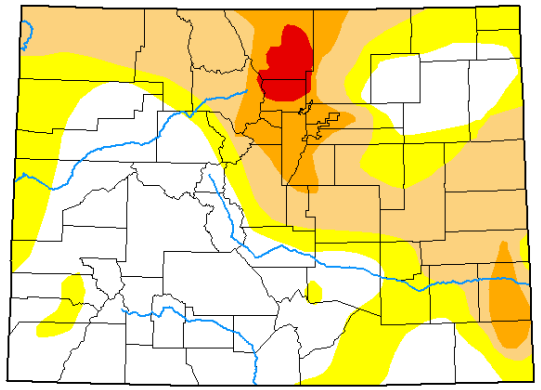
this week's USDM period



recent precipitation



U.S. Drought Monitor
Colorado



October 22, 2024
(Released Thursday, Oct. 24, 2024)
Valid 8 a.m. EDT

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	44.43	55.57	33.13	8.51	1.59	0.00
Last Week 10-15-2024	29.78	70.22	40.67	12.14	1.59	0.00
3 Months Ago 07-23-2024	64.30	35.70	7.85	1.32	0.00	0.00
Start of Calendar Year 01-02-2024	34.65	65.35	29.59	8.85	2.05	0.00
Start of Water Year 10-01-2024	48.27	51.73	24.40	4.62	0.00	0.00
One Year Ago 10-24-2023	57.87	42.13	22.23	4.43	0.00	0.00

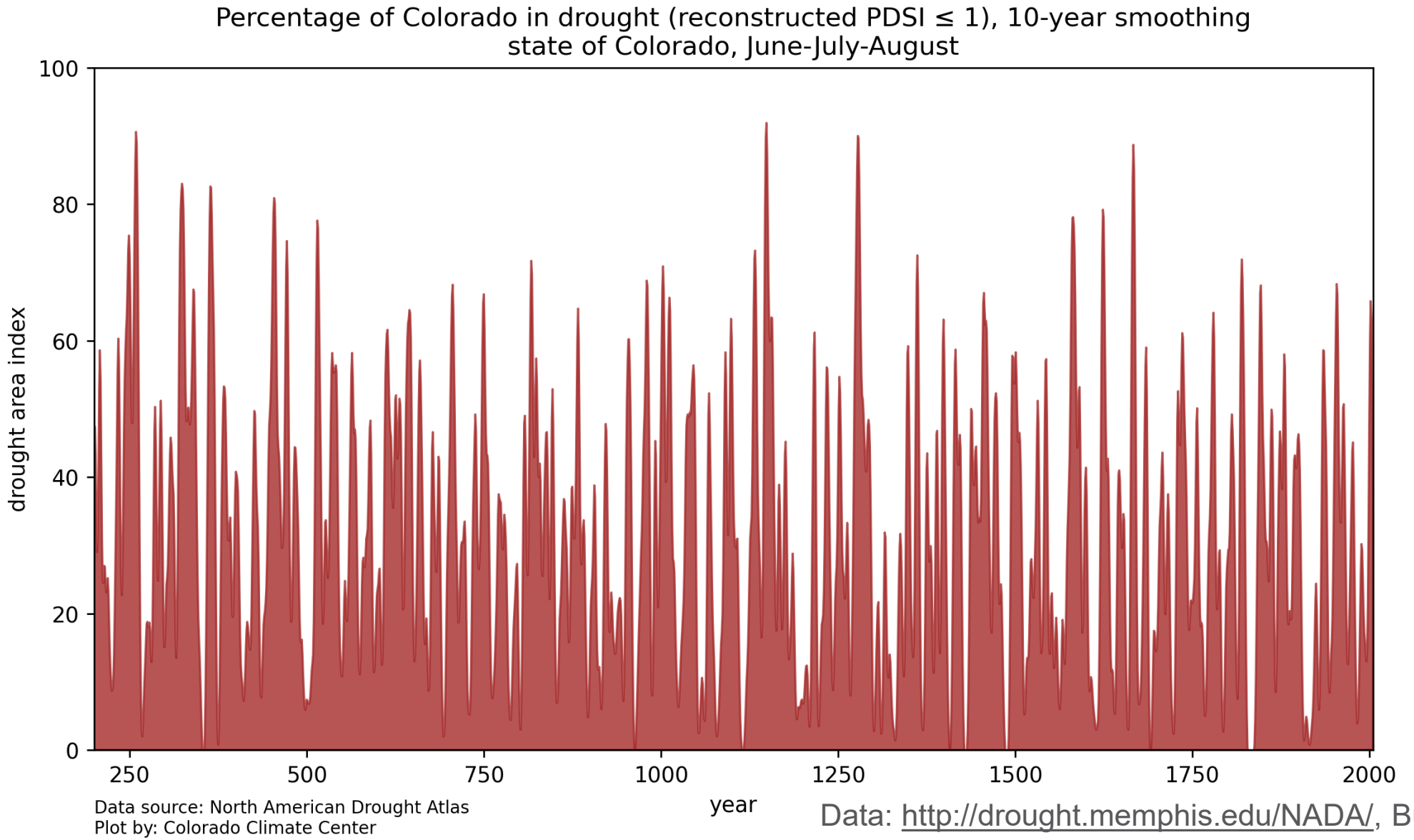
Intensity:
- None
- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. For more information on the Drought Monitor, go to https://droughtmonitor.unl.edu/About.aspx

Author:
Rocky Bilotta
NCEI/NOAA

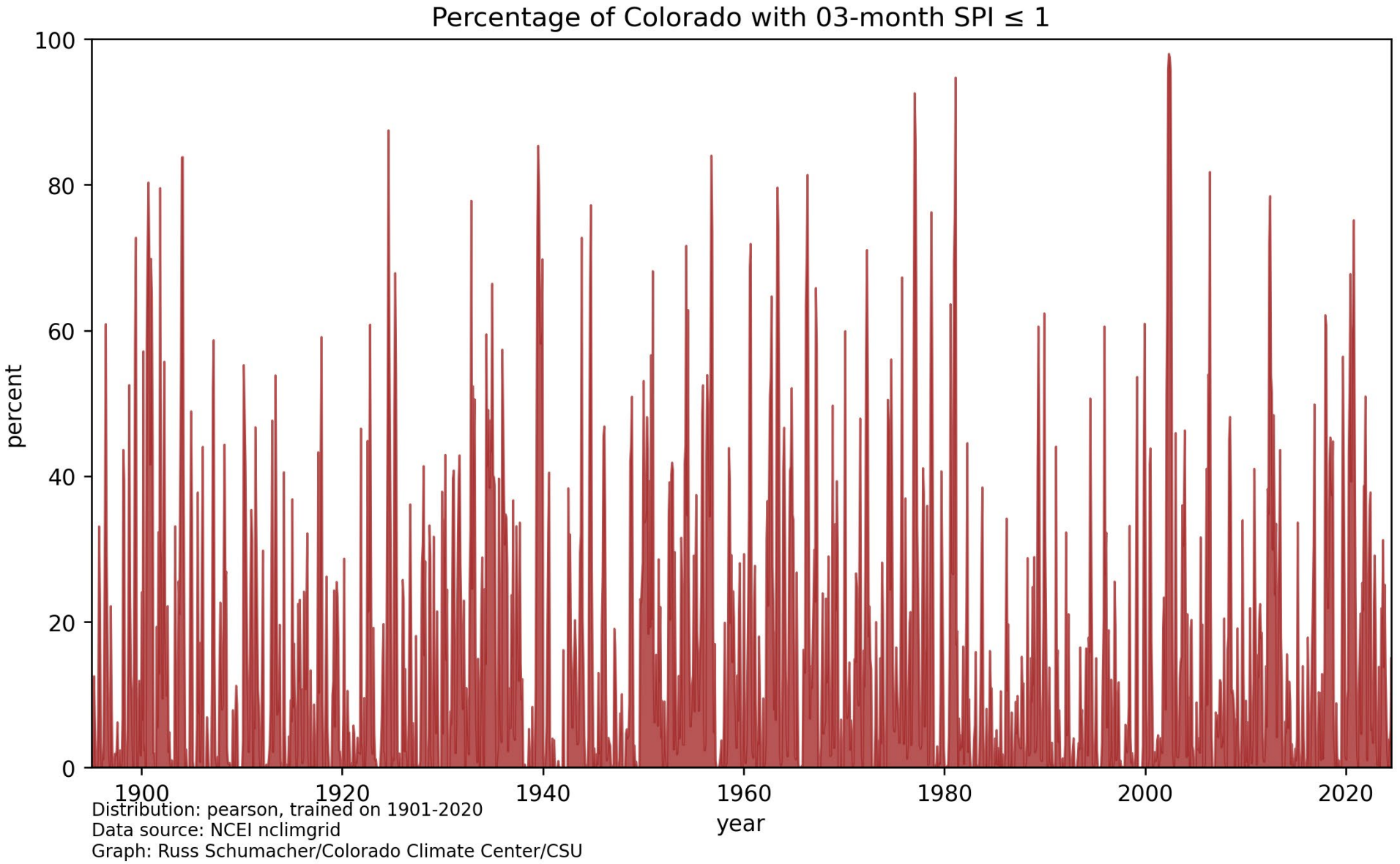
droughtmonitor.unl.edu

Percent of Colorado in drought (paleo reconstruction)



Data: http://drought.memphis.edu/NADA/, Burnette (2021)

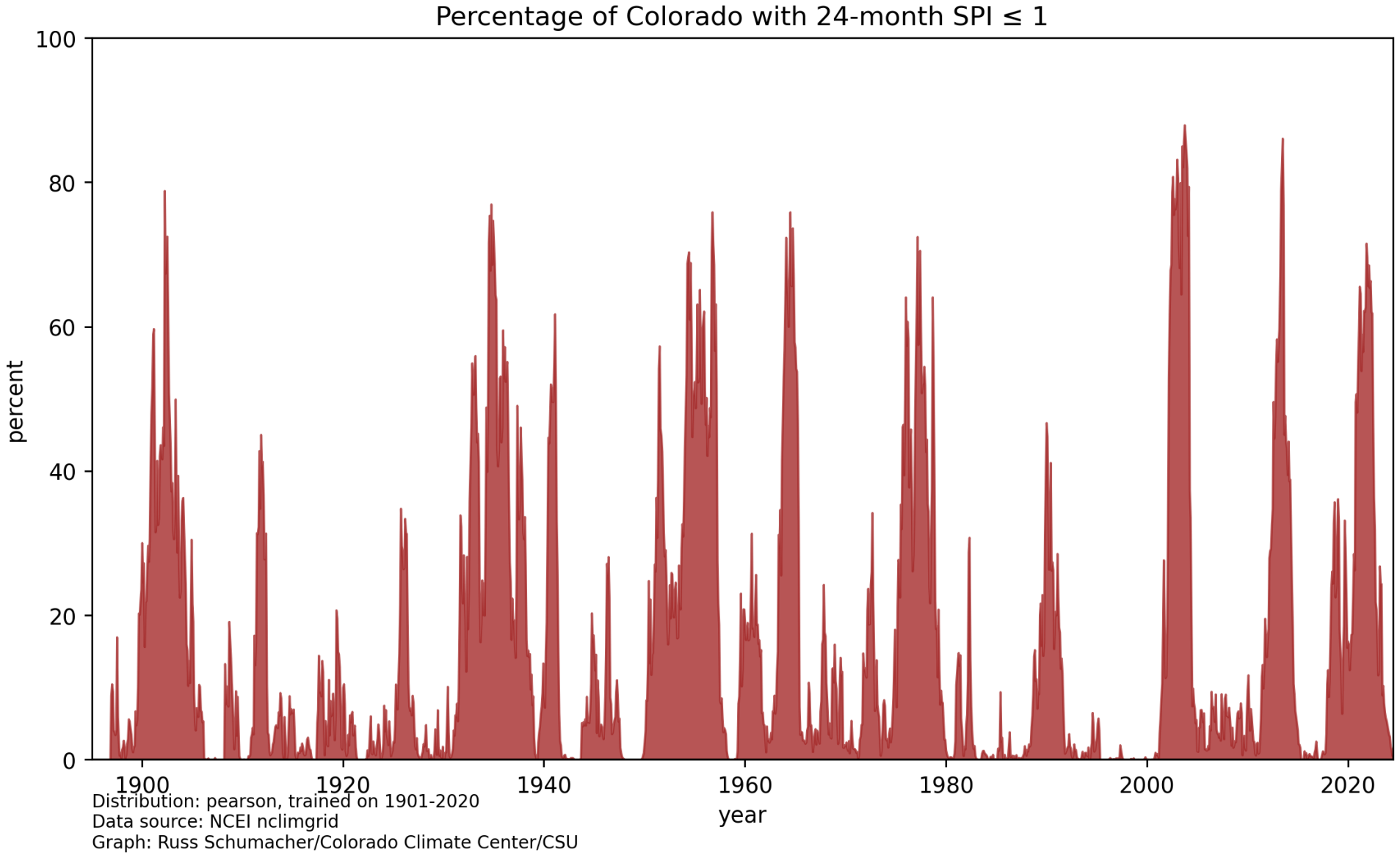
Percent of Colorado in short-term drought (since 1895)



Over a timescale of a few months, there's almost always somewhere in Colorado that's dry!

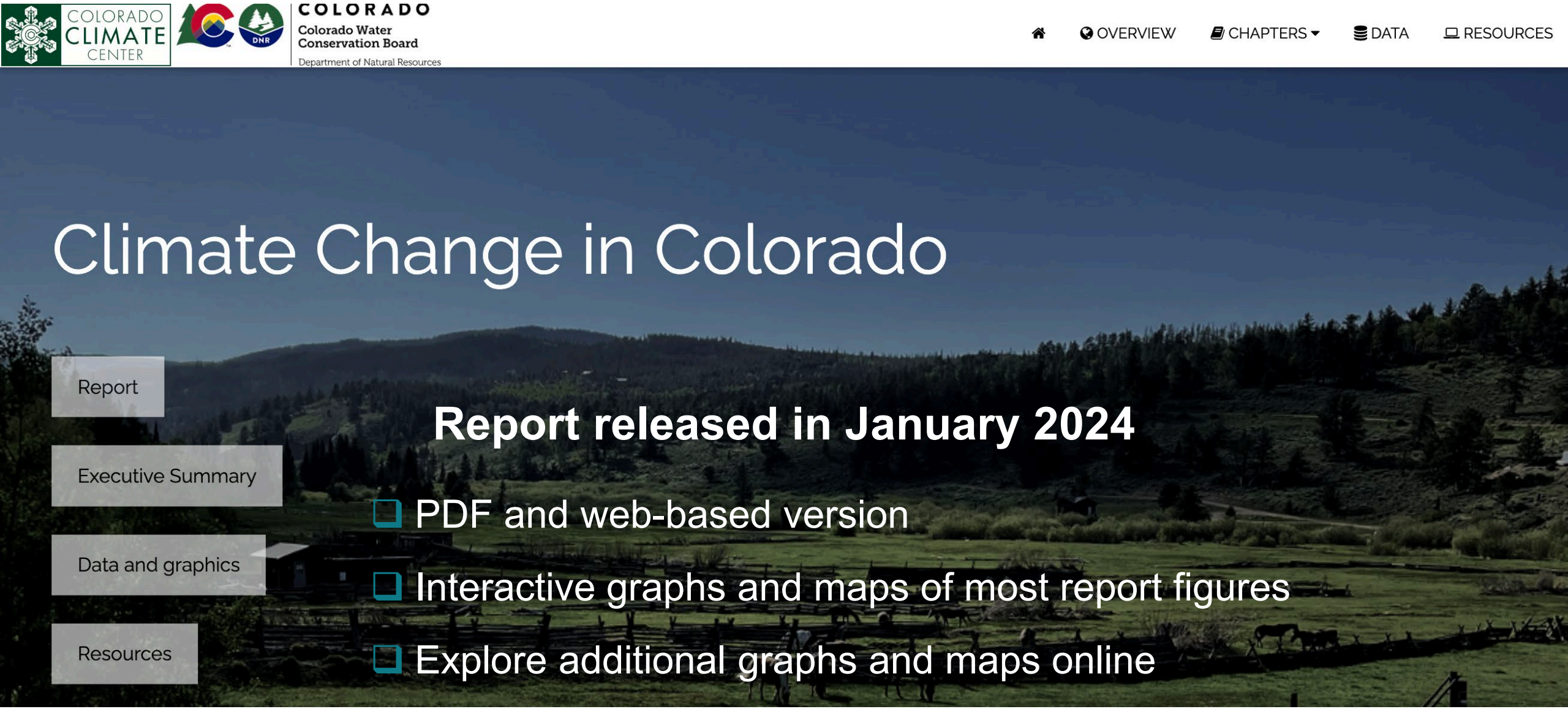
Considers precipitation only

Percent of Colorado in long-term drought (since 1895)



Here we see the persistent droughts that people tend to remember

Considers precipitation only



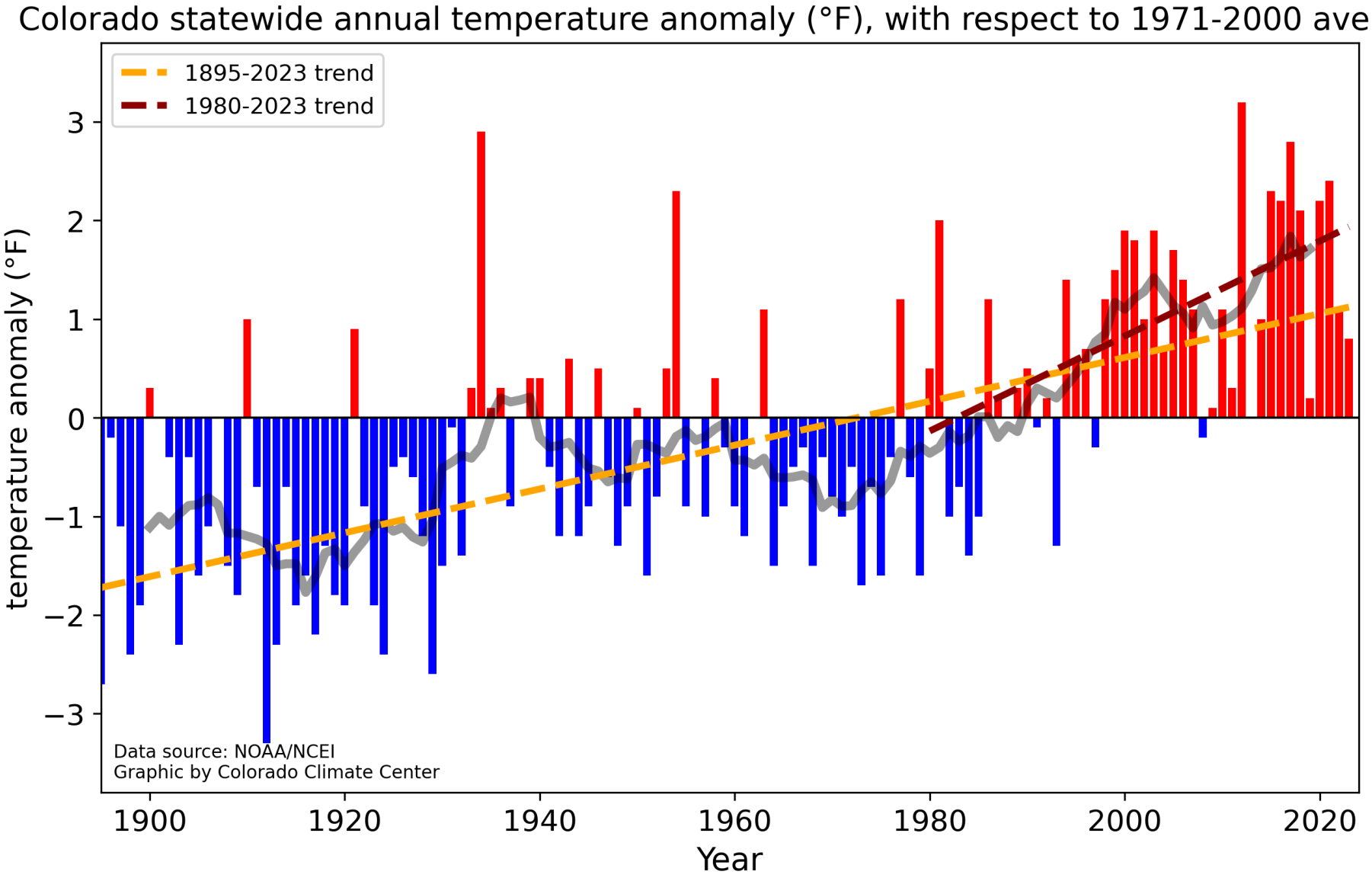
https://climatechange.colostate.edu

Thanks to Becky Bolinger, Jeff Lukas, Peter Goble

Chapter 2 – temperature and precipitation

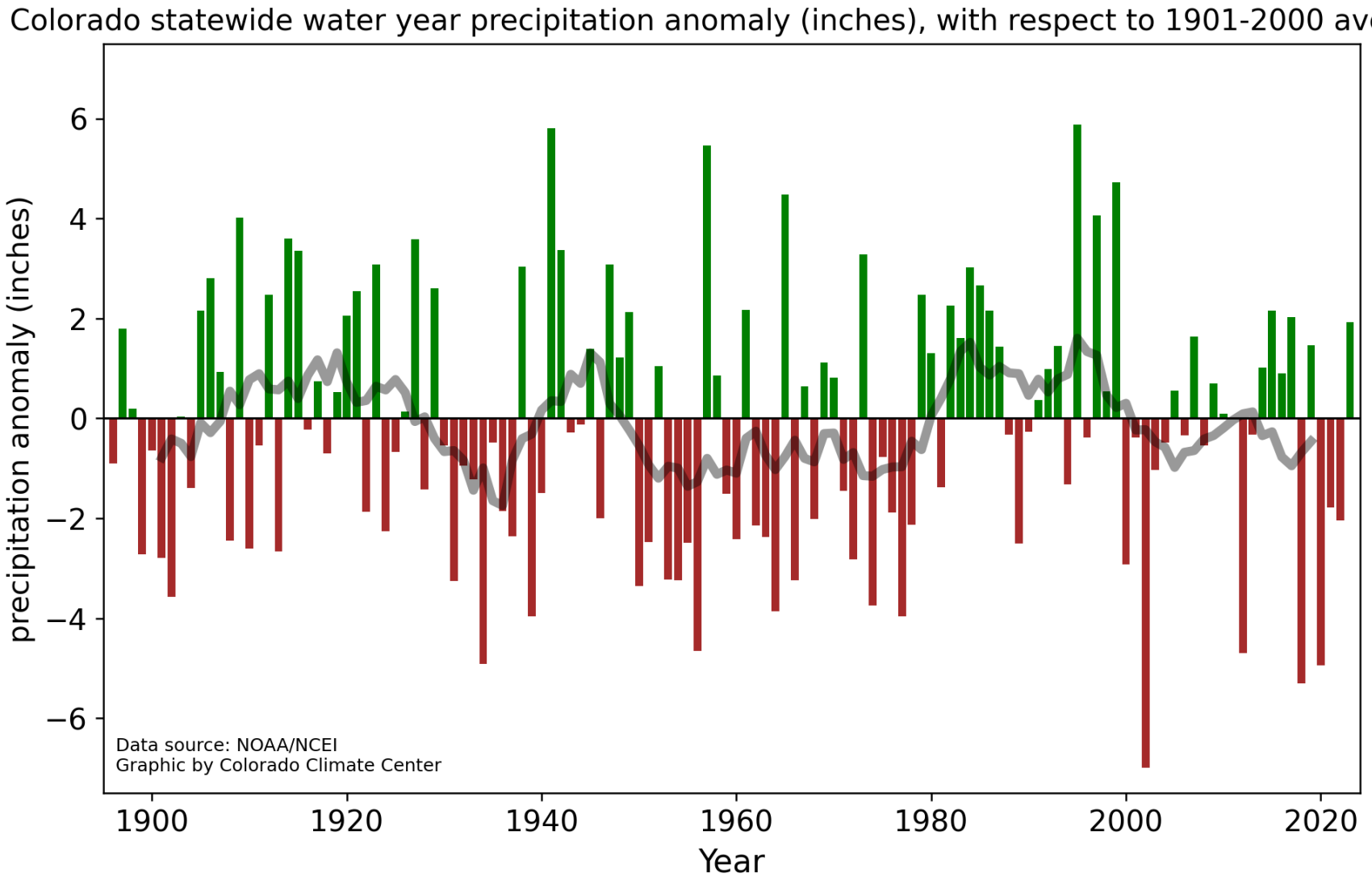
Climate variable/event	Recent trend	Projected future change	Confidence in change
Average Temperature	Warmer	Warmer	***Very high***
Annual Precipitation	Lower	Uncertain	*Low*

Temperature – observed changes

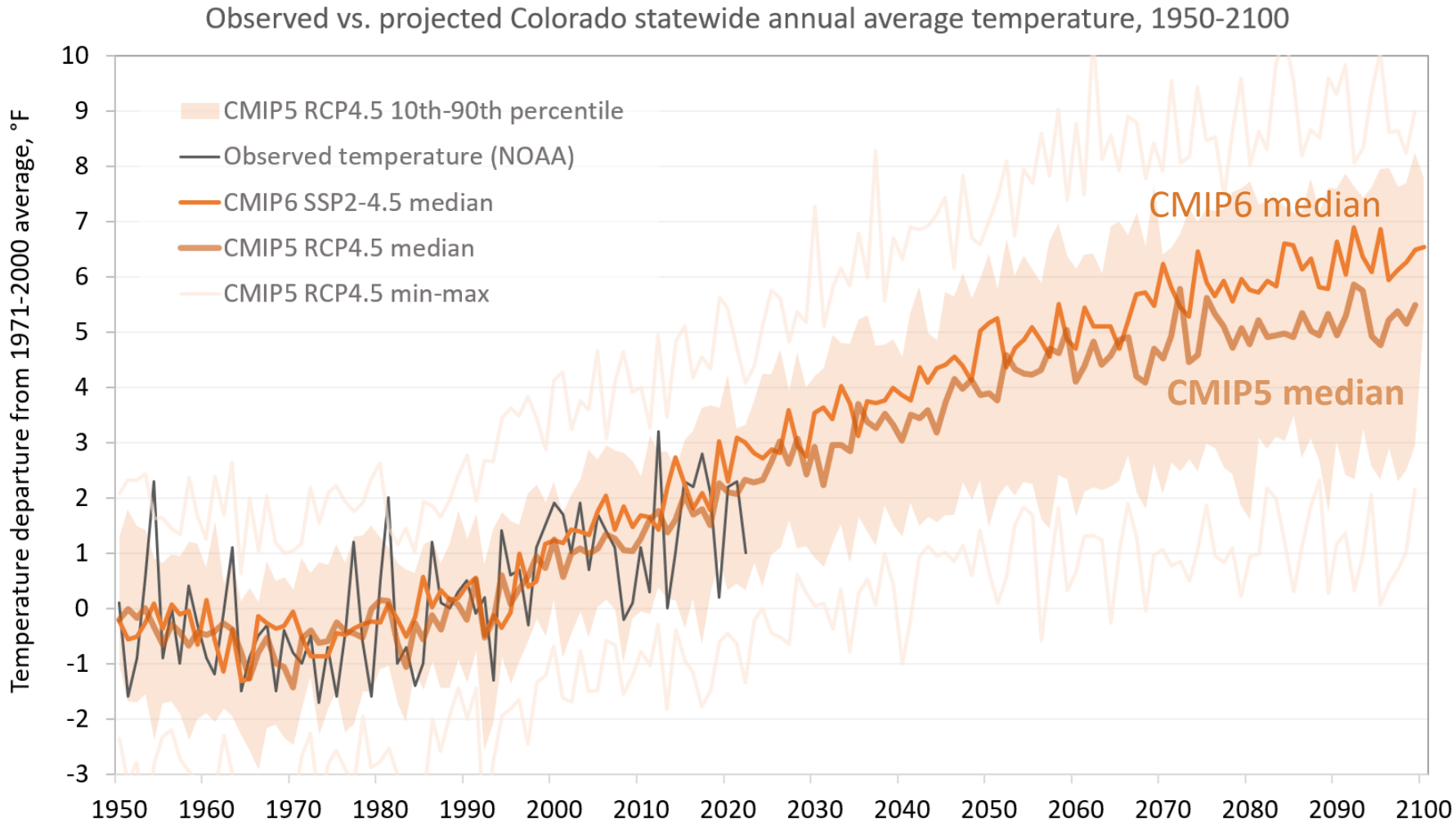


7 of the 9 warmest years on record have been since 2012

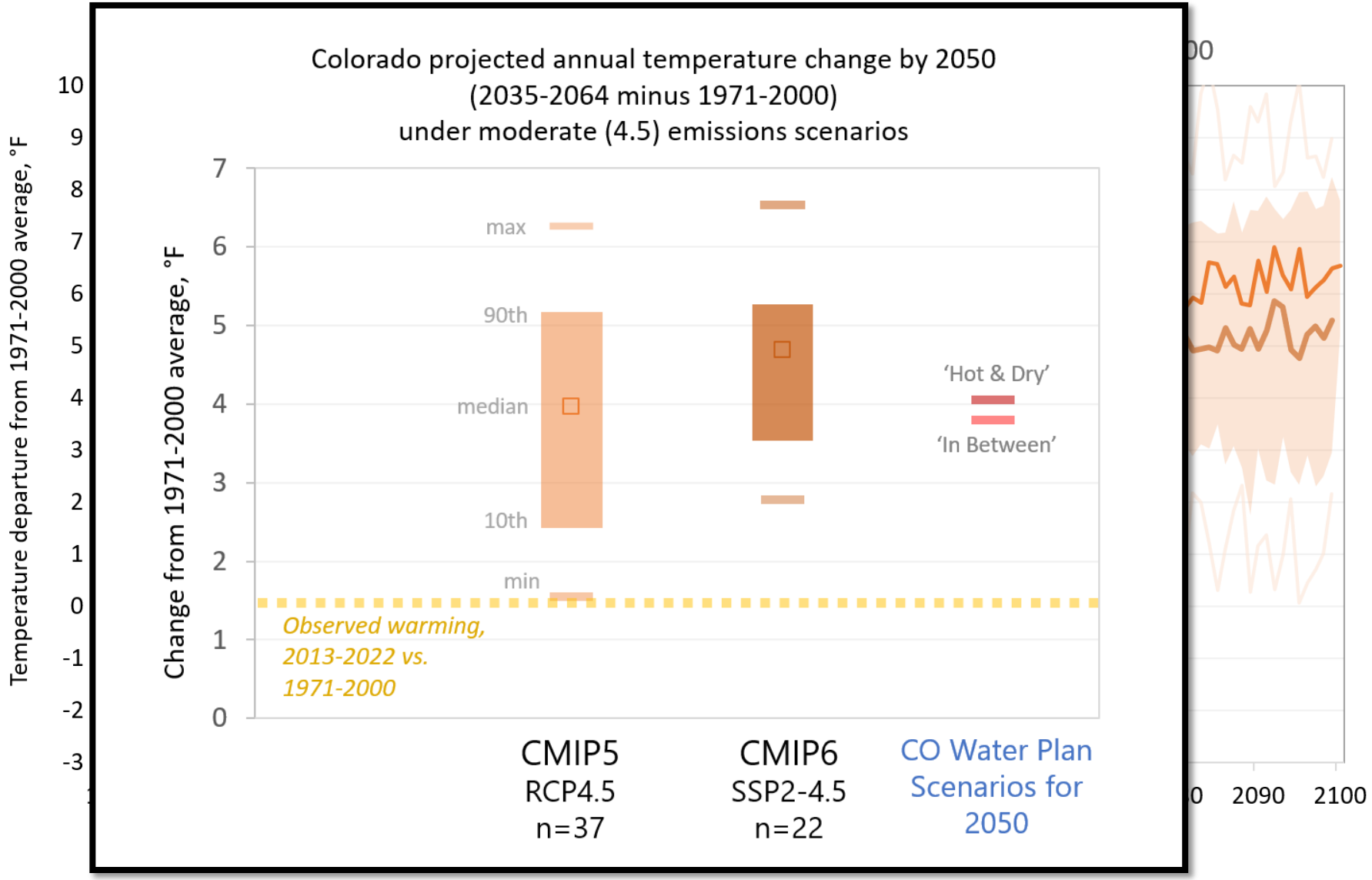
Precipitation – observed changes



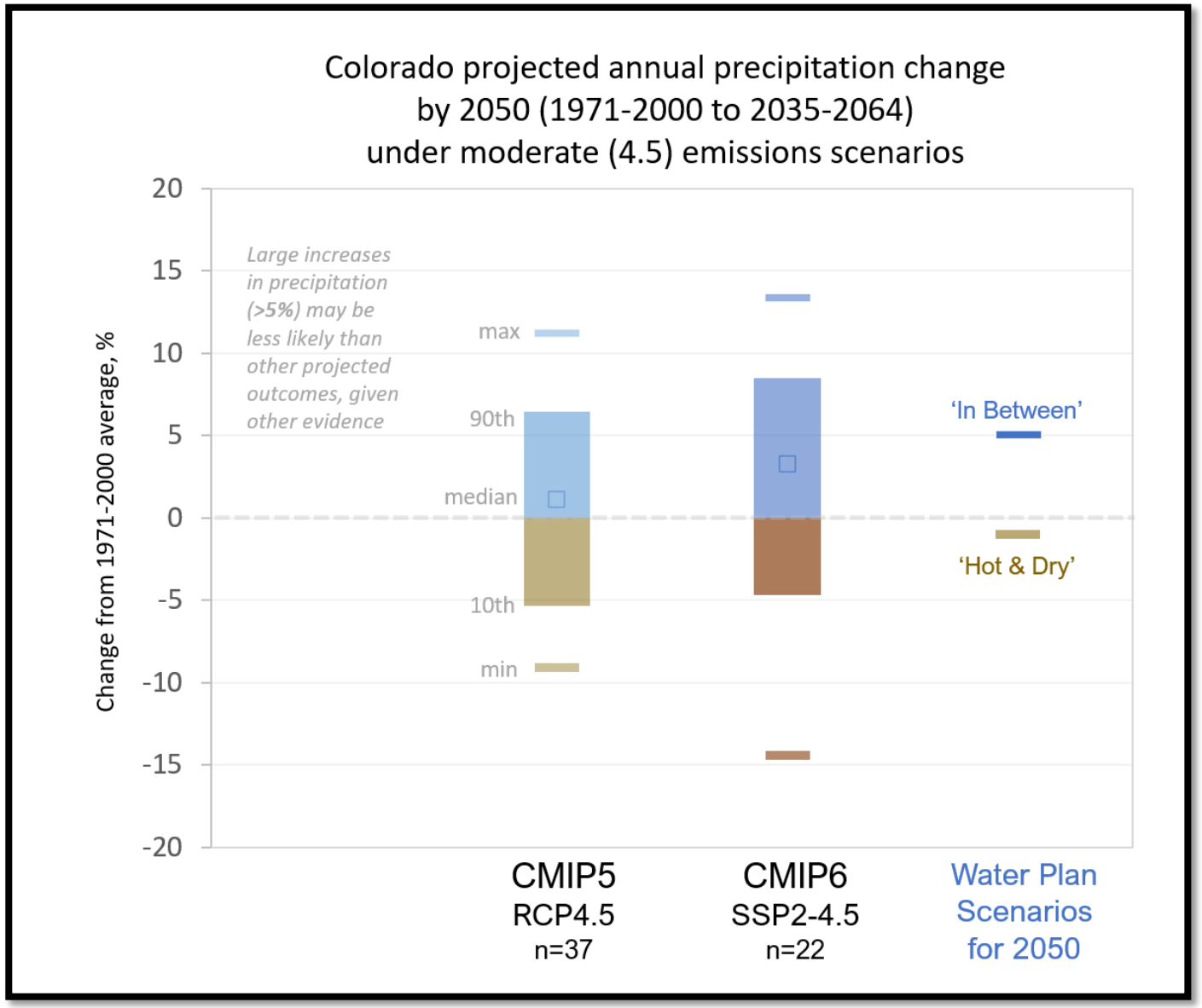
Temperature – future projections under moderate future emissions scenario



Temperature – future projections



Precipitation – future projections



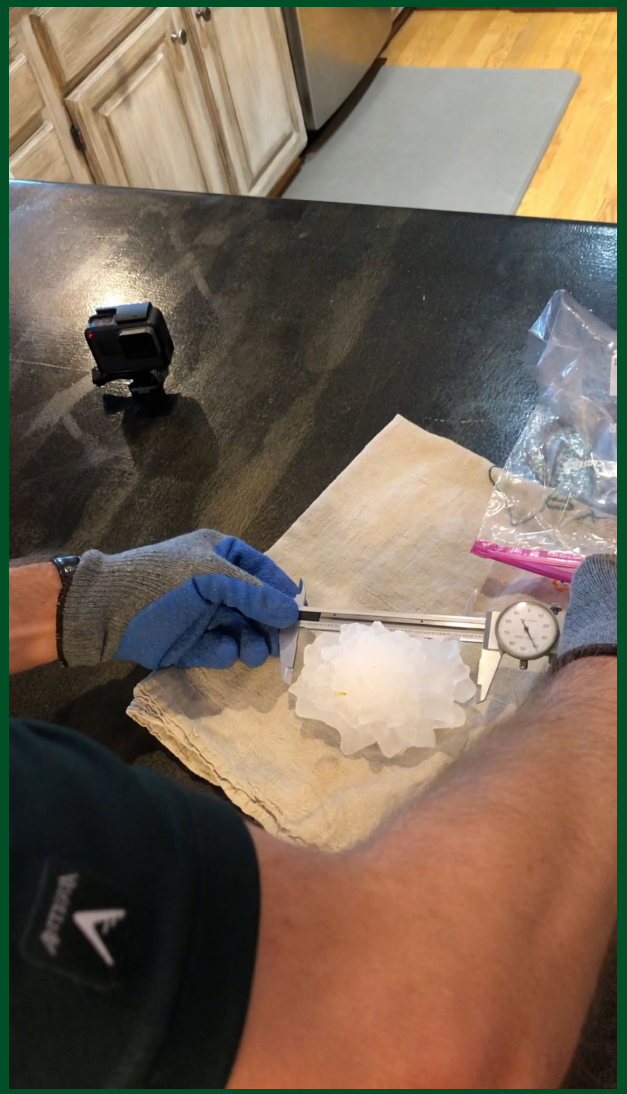
Chapter 3 – Colorado's water

Climate variable/event	Recent trend	Projected future change	Confidence in change
Spring Snowpack	Lower	Lower	*Medium*
Runoff timing	Earlier	Earlier	***High***
Annual Streamflow	Lower	Lower	*Medium*
Evaporative demand	Higher	Higher	***Very high***
Summer soil moisture	Lower	Lower	***High***

Chapter 4 – Hazards and Extremes

Climate variable/event	Recent trend	Projected future change	Confidence in change
Heat waves	More frequent/intense	More frequent/intense	***Very high***
Cold waves	Fewer	Fewer	***High***
Droughts	More frequent/intense	More frequent/intense	***High***
Wildfire threat	Higher	Higher	***High***
Extreme precipitation	Higher?	More frequent/intense	*Medium*
Flooding risk	Mixed	Higher	*Medium*
Windstorms	Uncertain	Uncertain	*Low*
Summer storms	Uncertain	More frequent?	*Low*
Winter storms	Uncertain	Larger storms?	*Low*
Dust on snow events	Higher dust levels	Higher dust levels	*Medium*

State record hailstones: August 13th, 2019, and exceeded on August 8, 2023



4.83” diameter, Bethune, August 13, 2019 (still holds the record for weight and circumference)

Photo courtesy Dan Fitts

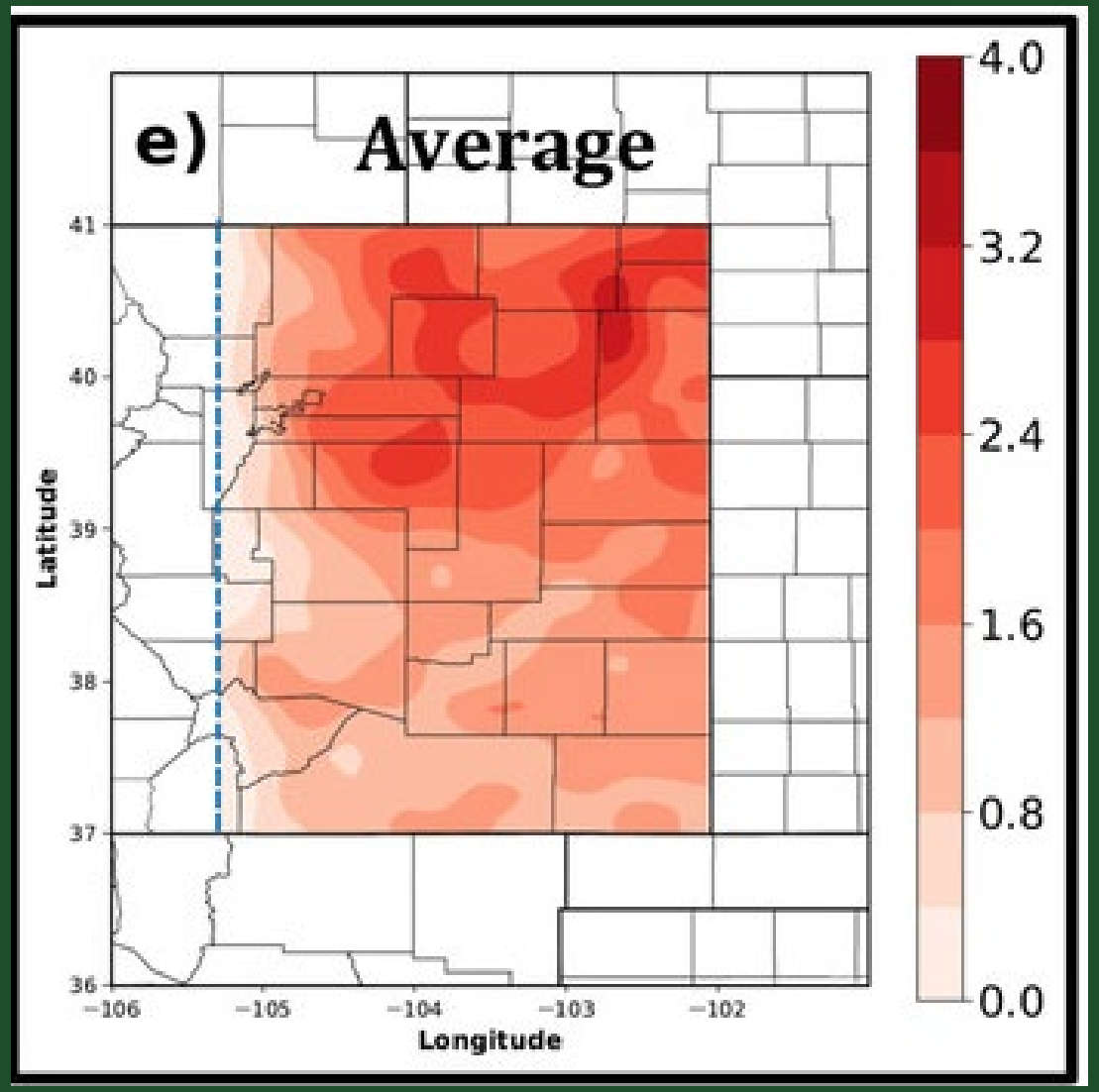
5.25” diameter, a new state record Yuma County, August 8, 2023

https://www.ncei.noaa.gov/monitoring-content/extremes/scec/reports/20230926-Colorado-Hailstone.pdf

Changes in hail risk

- Based on downscaled climate projections, Childs et al. (2020) found up to 3 more days of severe hail per year by 2100 in northern Colorado
- In a high population growth scenario, this could increase human exposure by 178%
- But another scenario is that the large hail shifts from the population centers to the eastern plains, which reduces human exposure but increases agricultural exposure

Change in number of days with severe hail (end of 21st century)



Research by former PhD student Sam Childs

Career discussion

- **Water in the west: decision-making under deep uncertainty**

- This will continue to be a major issue that needs to be informed by many disciplines, preferably working together!
  - Engineering, climate, natural resources, business, agriculture, ecology, policy, humanities, equity, …
  - Think and engage with the issues broadly – this is the kind of approach where you can bring value and help solve real problems

https://www.whitehouse.gov/ostp/news-updates/2021/10/12/expanding-and-improving-climate-information-and-services-for-the-public/

Every day, Americans make decisions that affect their resilience to climate change. How much water will their crops or livestock need this year? How high should a bridge be built to withstand future flooding over the next 50 to 100 years? Where should they purchase a home without worrying about the risks of wildfire or storm surge to their property? Should they contact their child's football coach about policies for keeping players cool on extremely hot days? For how many years into the future will sea ice be safe to hunt on? Where should solar and wind energy infrastructure be sited so as to maximize production while minimizing wildlife conflicts?

Our report outlines a plan to work across agencies and with information users and partners to:

• Develop the robust set of actionable climate services that meet the needs of a diversity of users;

• Design and implement effective tools and equitable delivery mechanisms for climate services;

• Leverage the respective capabilities of Federal and private sector partners to spur innovation to create climate services that reach all communities; and

• Implement ambitious science and technology initiatives to better understand key unknowns about climate change and how people use services to continually improve and expand knowledge, engagement, and education, bolstering the effectiveness of service capabilities.

Rising to this challenge will require sustained and coordinated engagement – as well as periodic evaluation and adjustment – to ensure that Federal agencies and our partners develop climate services that are trusted, useful, and used by decision makers and the public.

https://www.whitehouse.gov/ostp/news-updates/2021/10/12/expanding-and-improving-climate-information-and-services-for-the-public/

Climate services: examples from the last month

"I have a question for you regarding adjusting climate normals for forecasting purposes. Each year at [water utility], we produce forecasts of annual demand for the upcoming year. In doing so, we use the last 30 years of historical weather for creating an ensemble range. However, it has become evident that conditions have warmed enough within our service area that using 30 years of historical data no longer produces the most reliable range of forecasts. What are your thoughts on a reasonable approach to take in shortening the historical weather timeframe utilized for making an annual demand forecast?"

Climate services: examples from the last month

"Could you help us by providing us with some recent drought information for this specific area [in western Colorado]? We are looking specifically for information on how the drought has affected the ecosystem or habitat in this area. Regional drying trends, decreasing snowpack and lower monsoonal rains, severity of impact caused by drought, increase of wildfire activity, etc."

Climate services

- Climate data has never been more available and accessible, but what decision makers need is knowledge and insights, and that's where climate services providers can help!
- Wide range of opportunities across government, academia, or private sector, with demand that is likely to continue growing

Thank you!

https://climate.colostate.edu/

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COLORADO CLIMATE CENTER

ATMOSPHERIC SCIENCE
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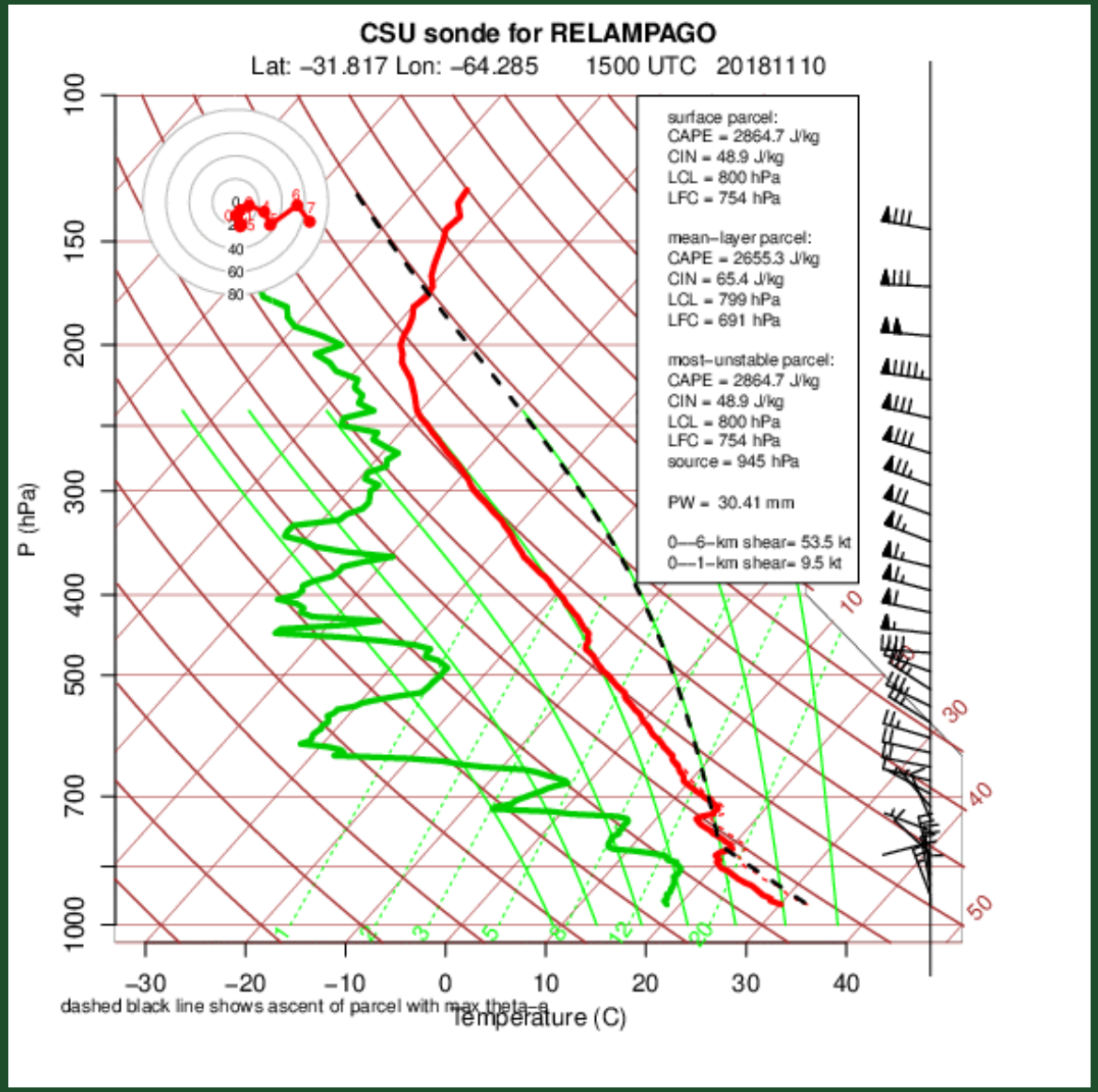
Field research: data collection near storms using mobile radiosonde systems

RELAMPAGO field campaign, Argentina, 2018



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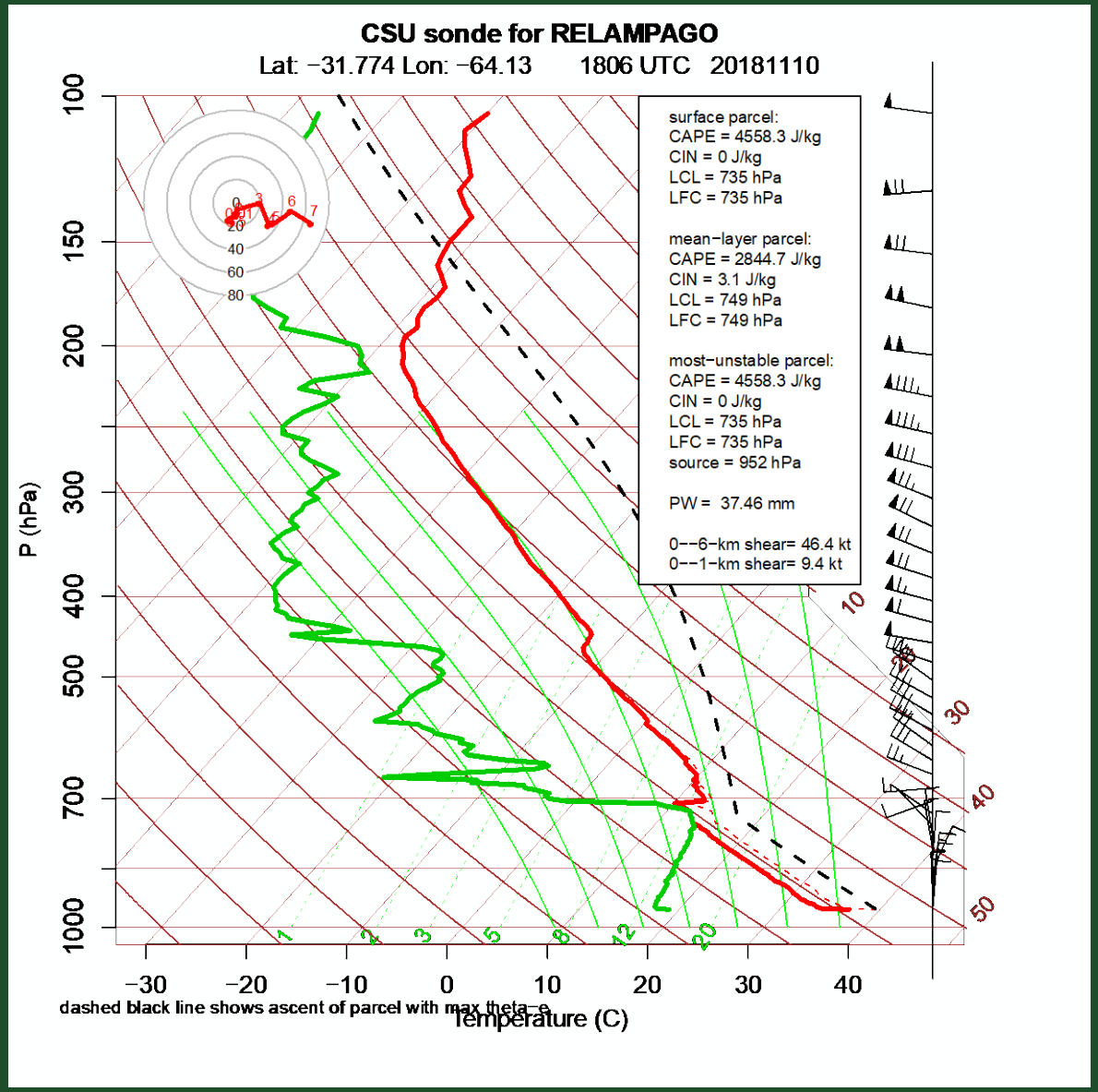
Field research: data collection near storms using mobile radiosonde systems



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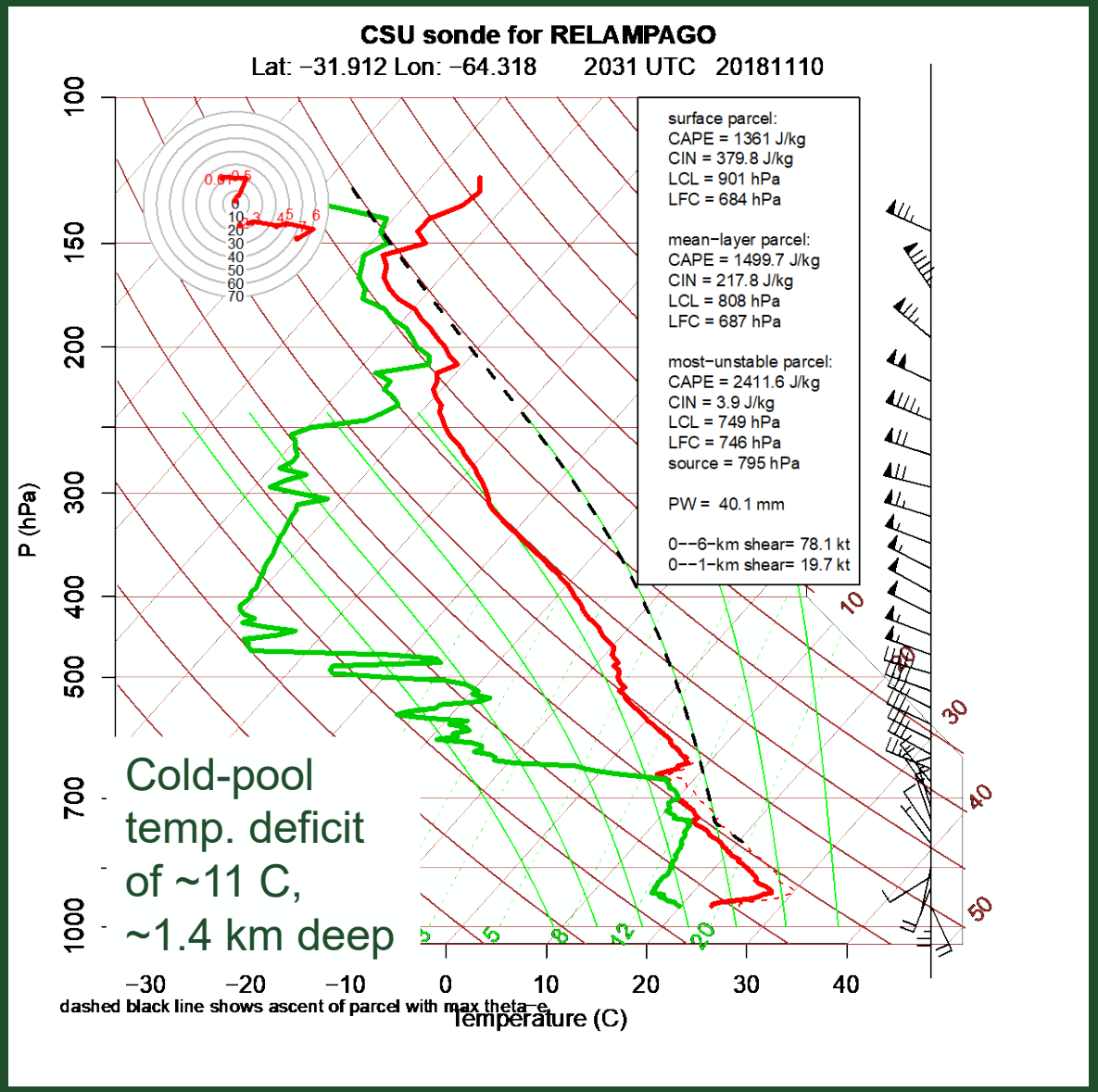
10 November 2018: supercell in RELAMPAGO domain



10 November 2018: supercell in RELAMPAGO domain

THE VERGE

THE VERGE

"We're trying our best to catch it," Schumacher replies. "Not sure we'll be able to."