

# Precipitation extremes in Colorado

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Along with: Peter Goble, Becky Bolinger, Zach Schwalbe, Nolan Doesken



ATMOSPHERIC SCIENCE  
COLORADO STATE UNIVERSITY

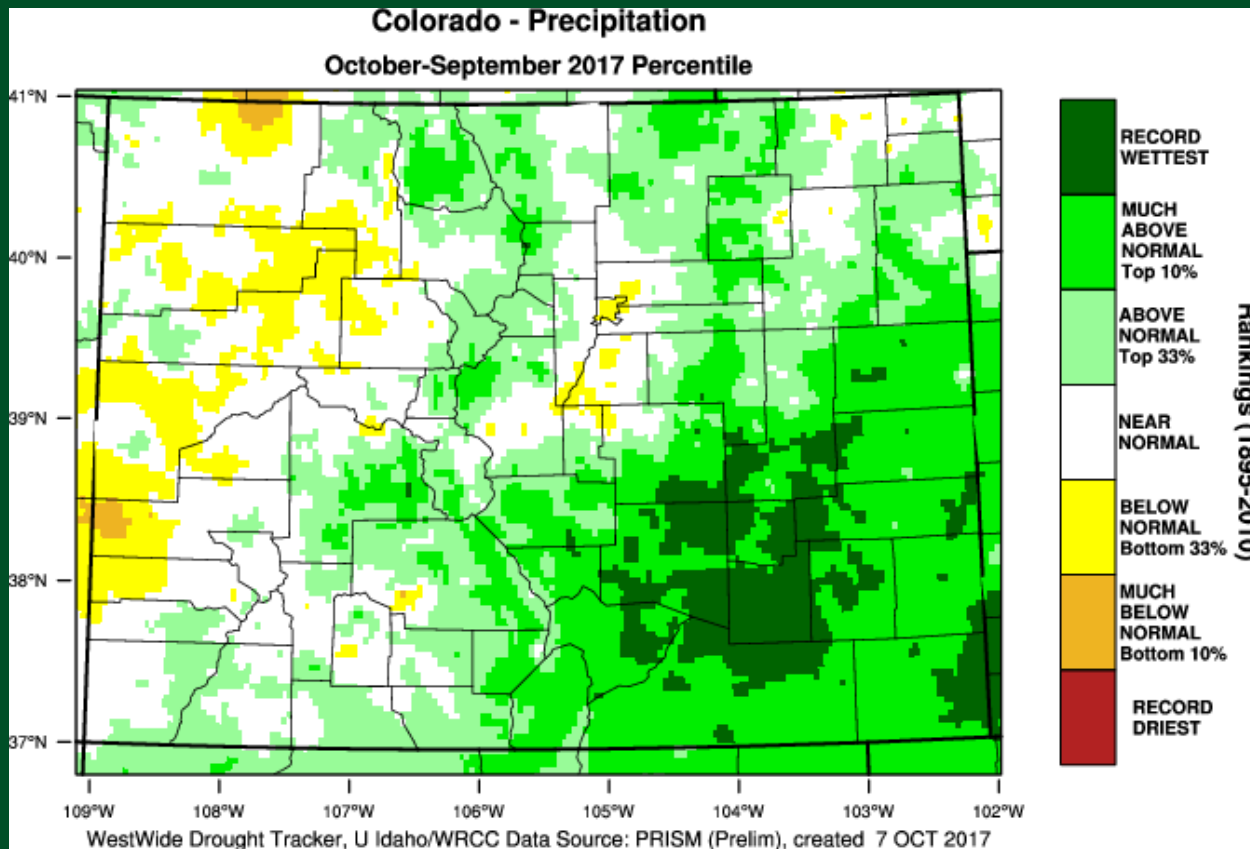


COLORADO CLIMATE CENTER  
*Providing information and expertise on Colorado's complex climate*

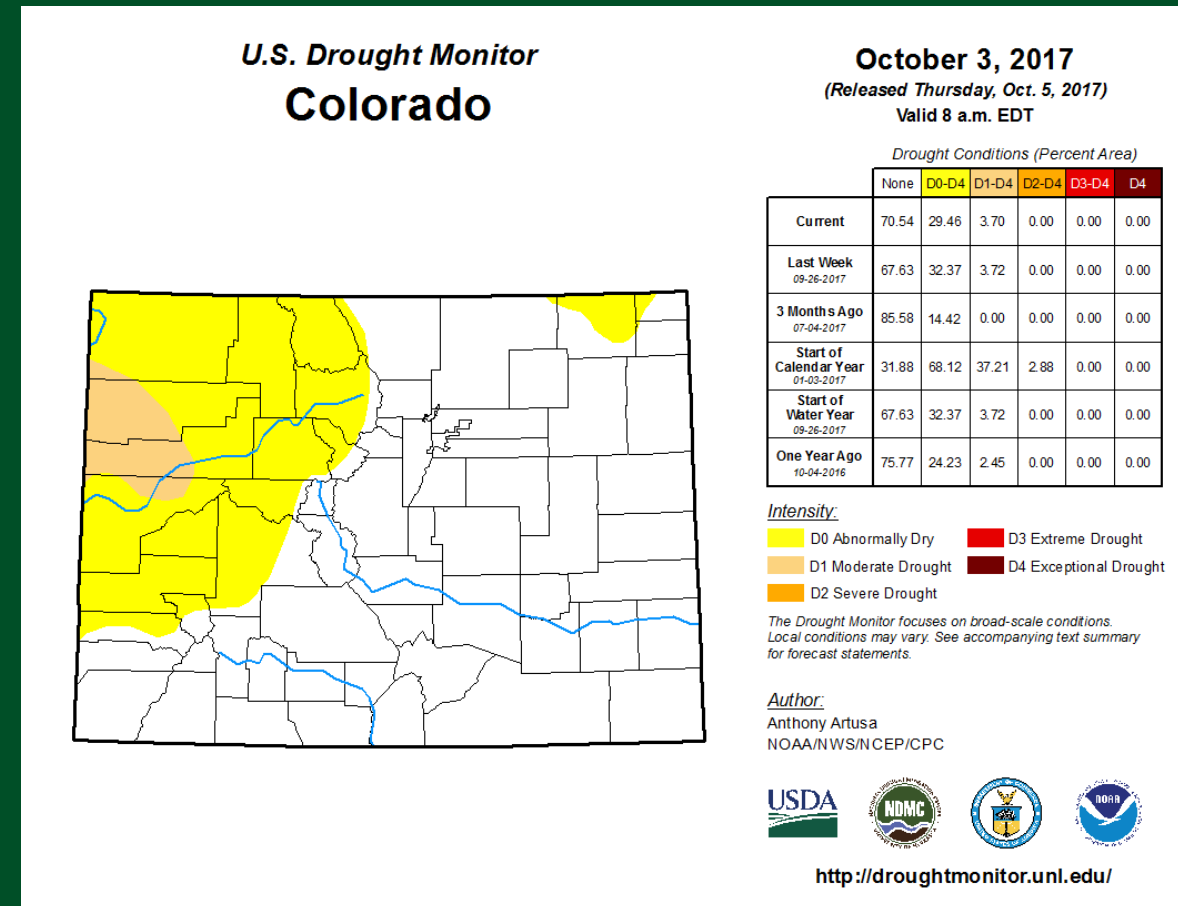
Colorado Water Congress  
25 January 2018



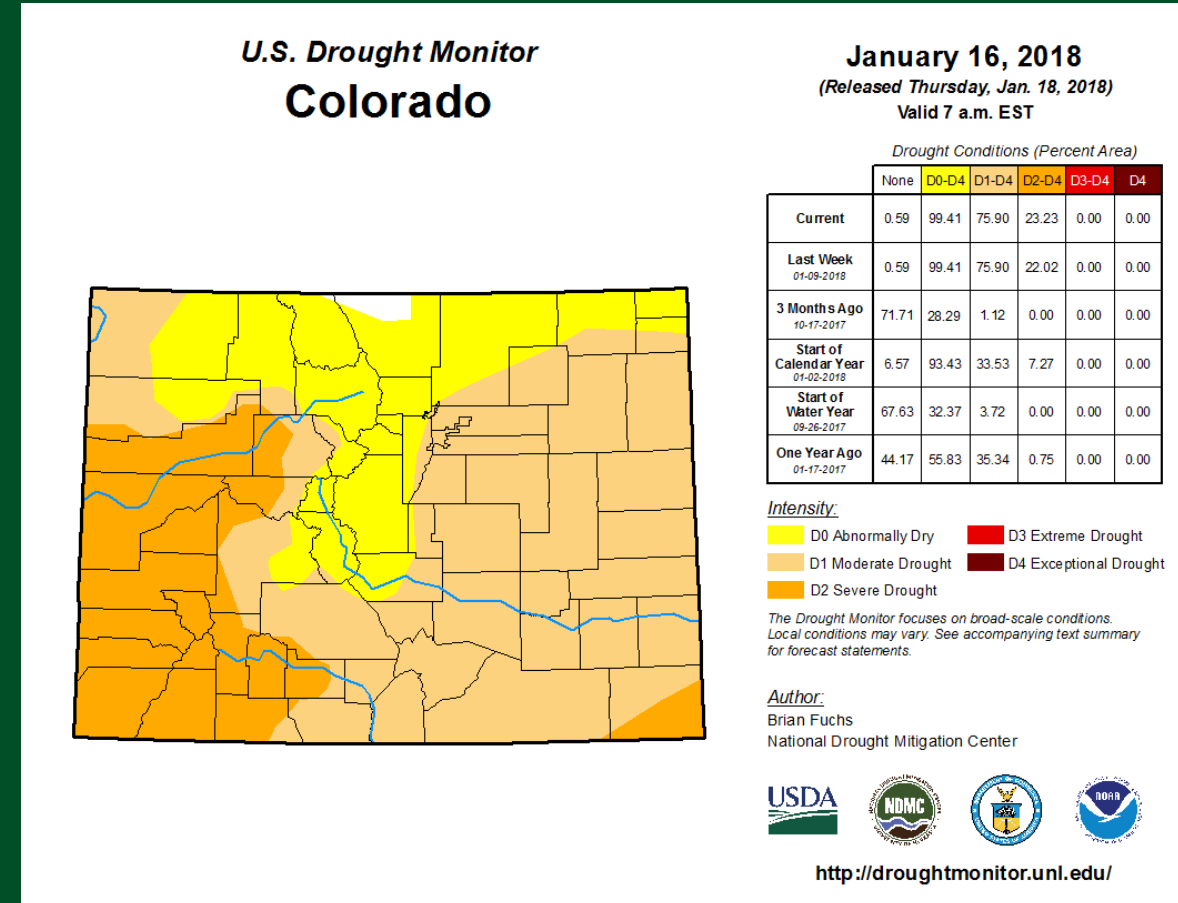
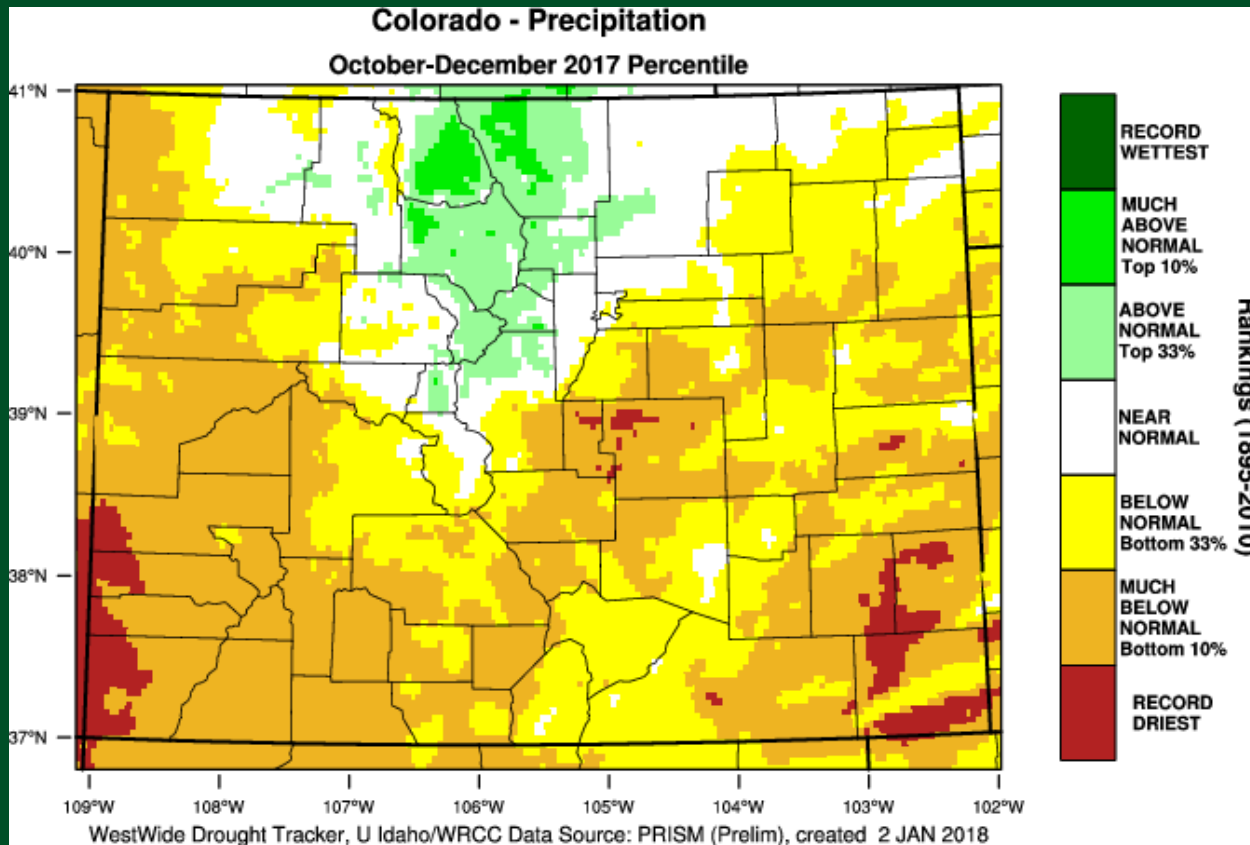
# Looking back to Water Year 2017...



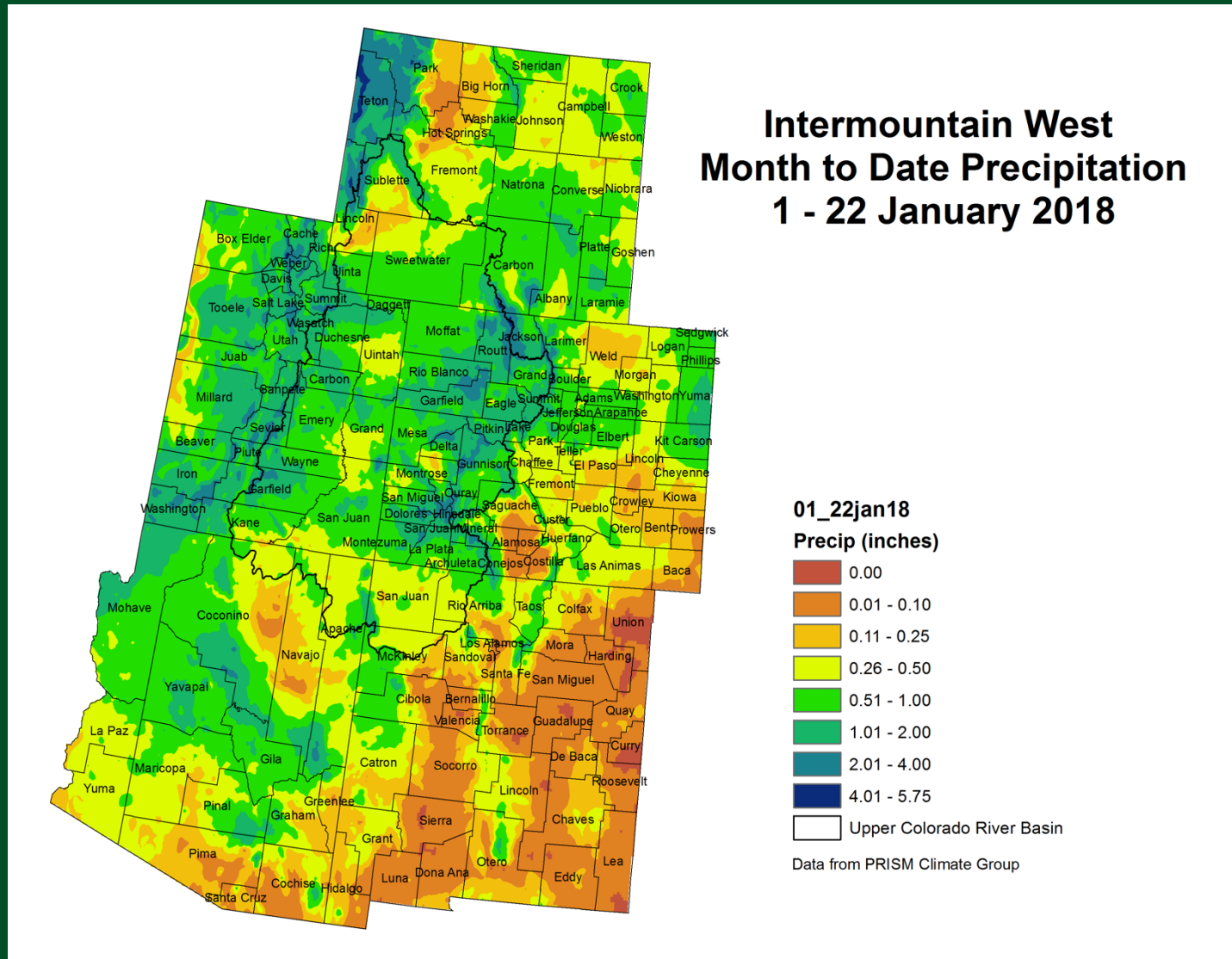
30<sup>th</sup> wettest water year on record



# But since: not a good start to WY 2018...

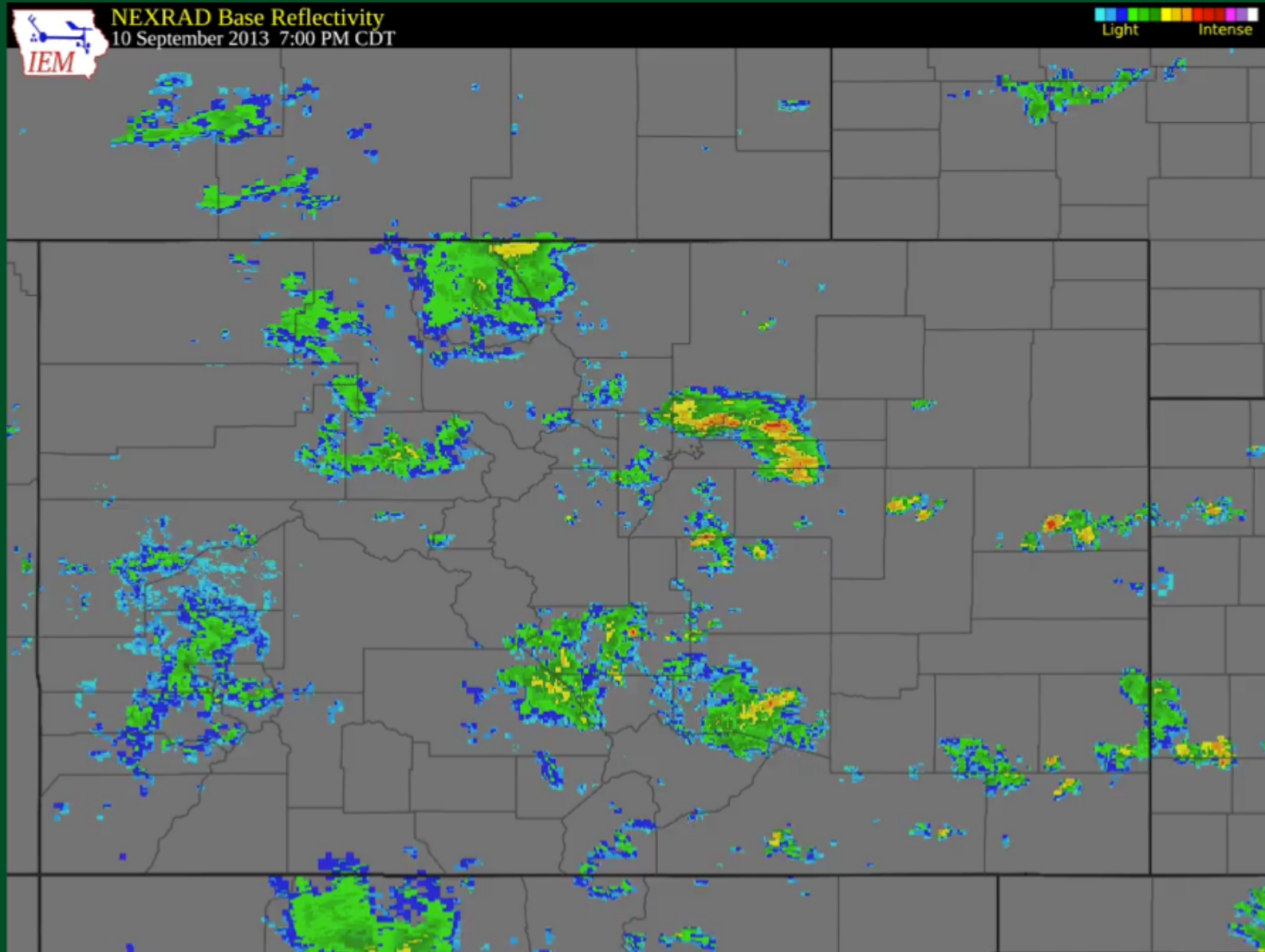


# January 2018: a little better, but still a long way to go



**Even when we're in drought, we can't forget to think about floods...**

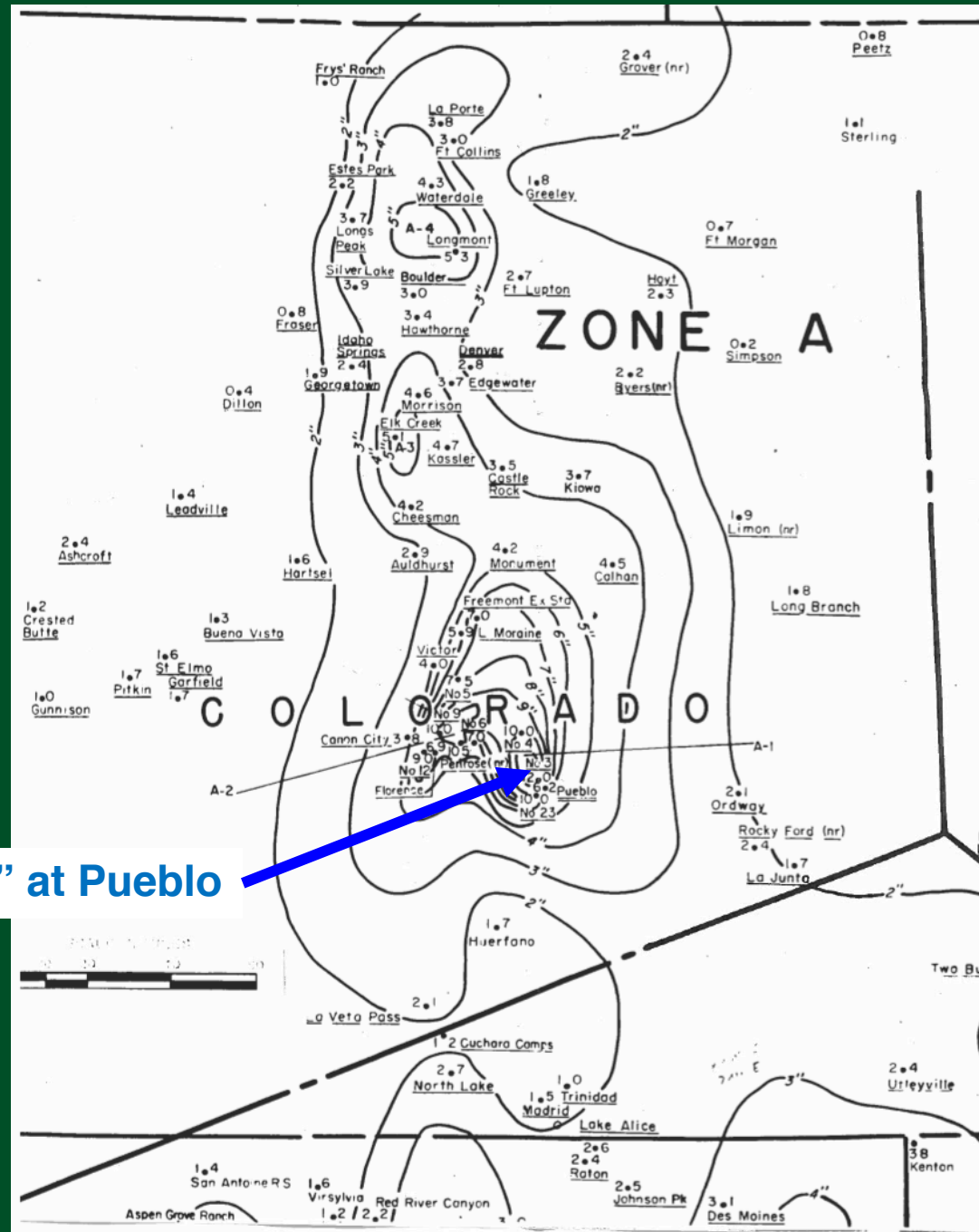
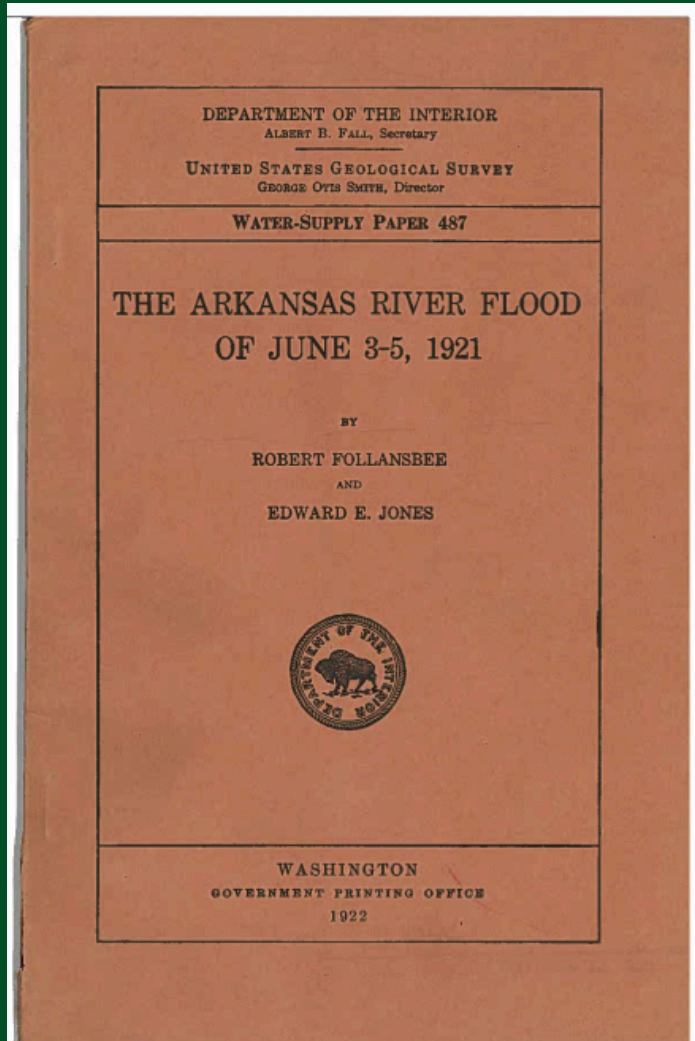
# A variety of time and space scales in a week of extreme rainfall



Animation from  
6:00pm  
September 10 –  
6:00am  
September 16  
2013

One image  
every 30  
minutes

# Of course floods aren't new in Colorado!

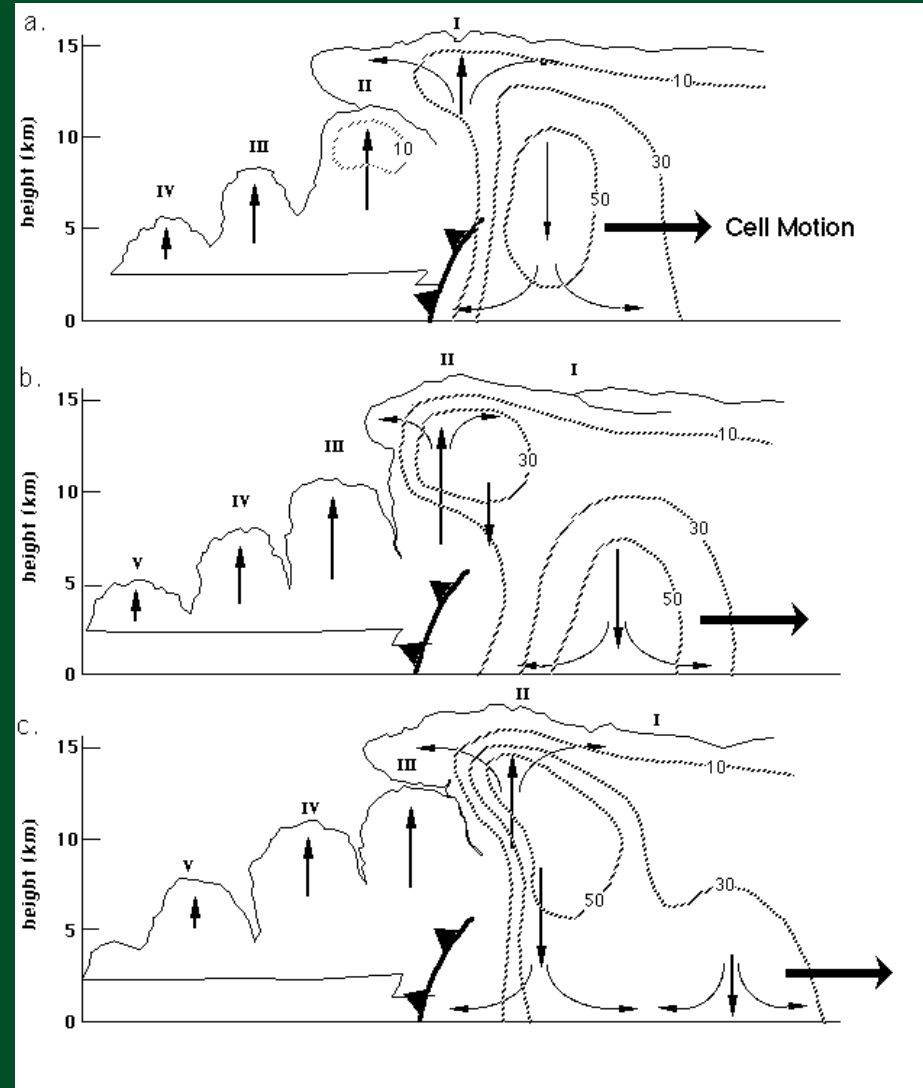
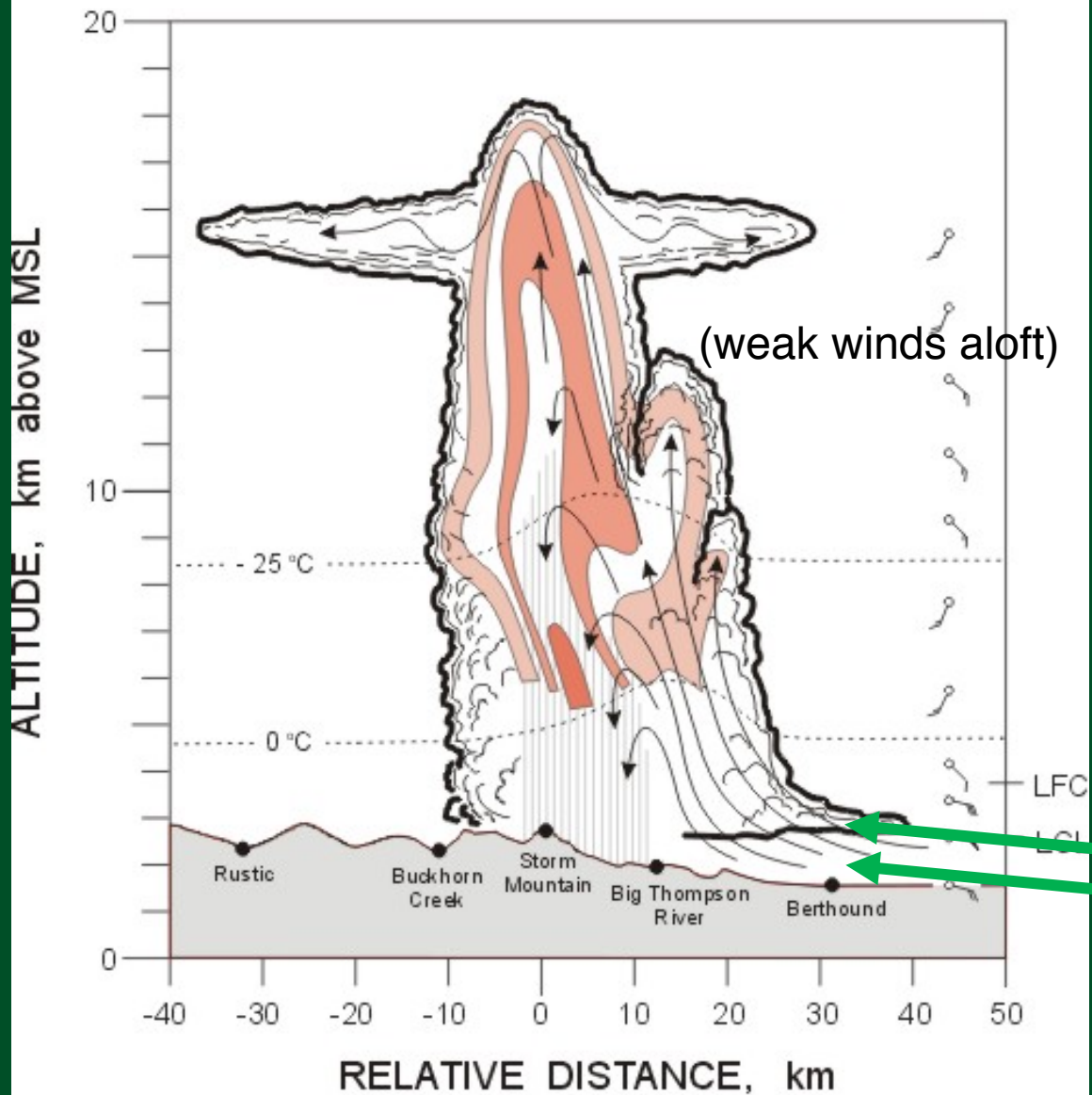




# Ingredients for extreme rainfall

- Simply:  $P = \bar{R}D$  (precipitation equals average rainfall rate times duration)
  - Or, in other words: the most rain falls where it rains the hardest for the longest!
  - This is sometimes called the “First Law of Quantitative Precipitation Forecasting”
- To get a high rain rate: need moist air going up!
  - Strong thunderstorms; forcing air up a mountain; etc.
  - Here in Colorado, usually it’s the moisture that’s lacking

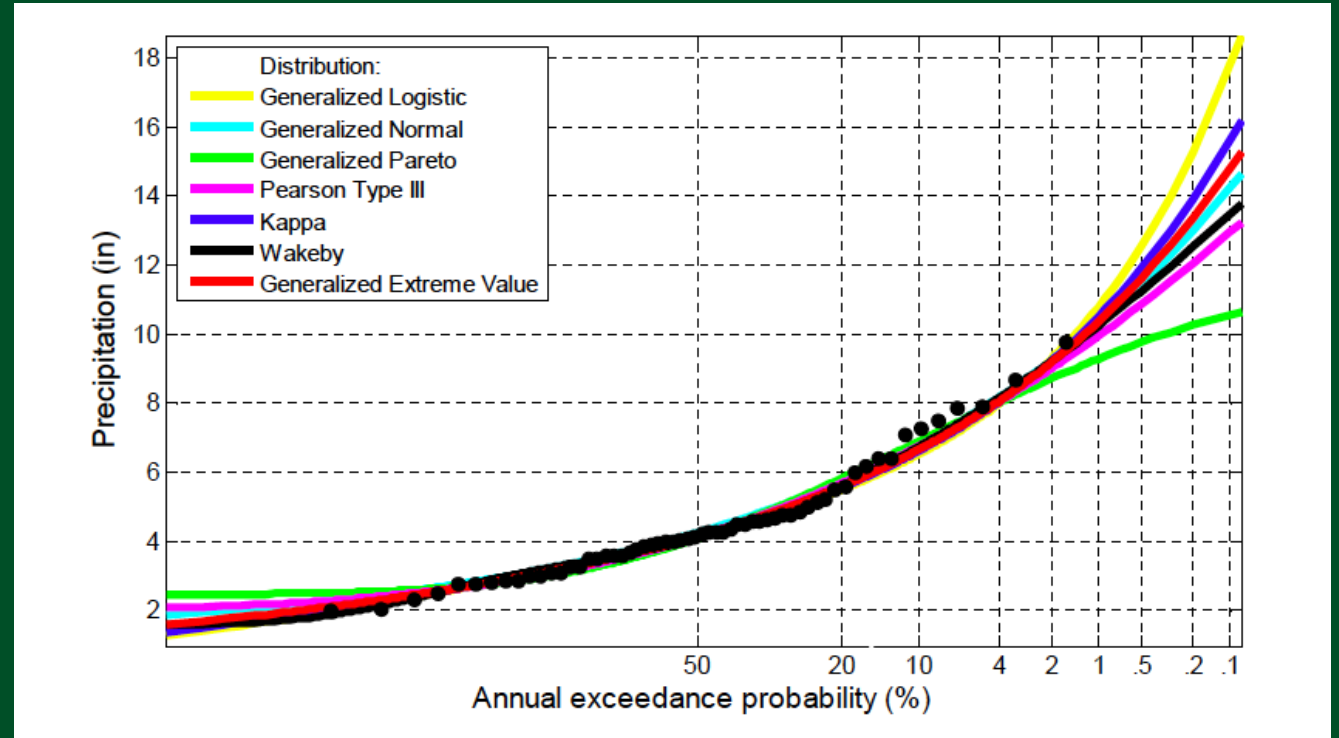
# BIG THOMPSON STORM



From Doswell et al. (1996)

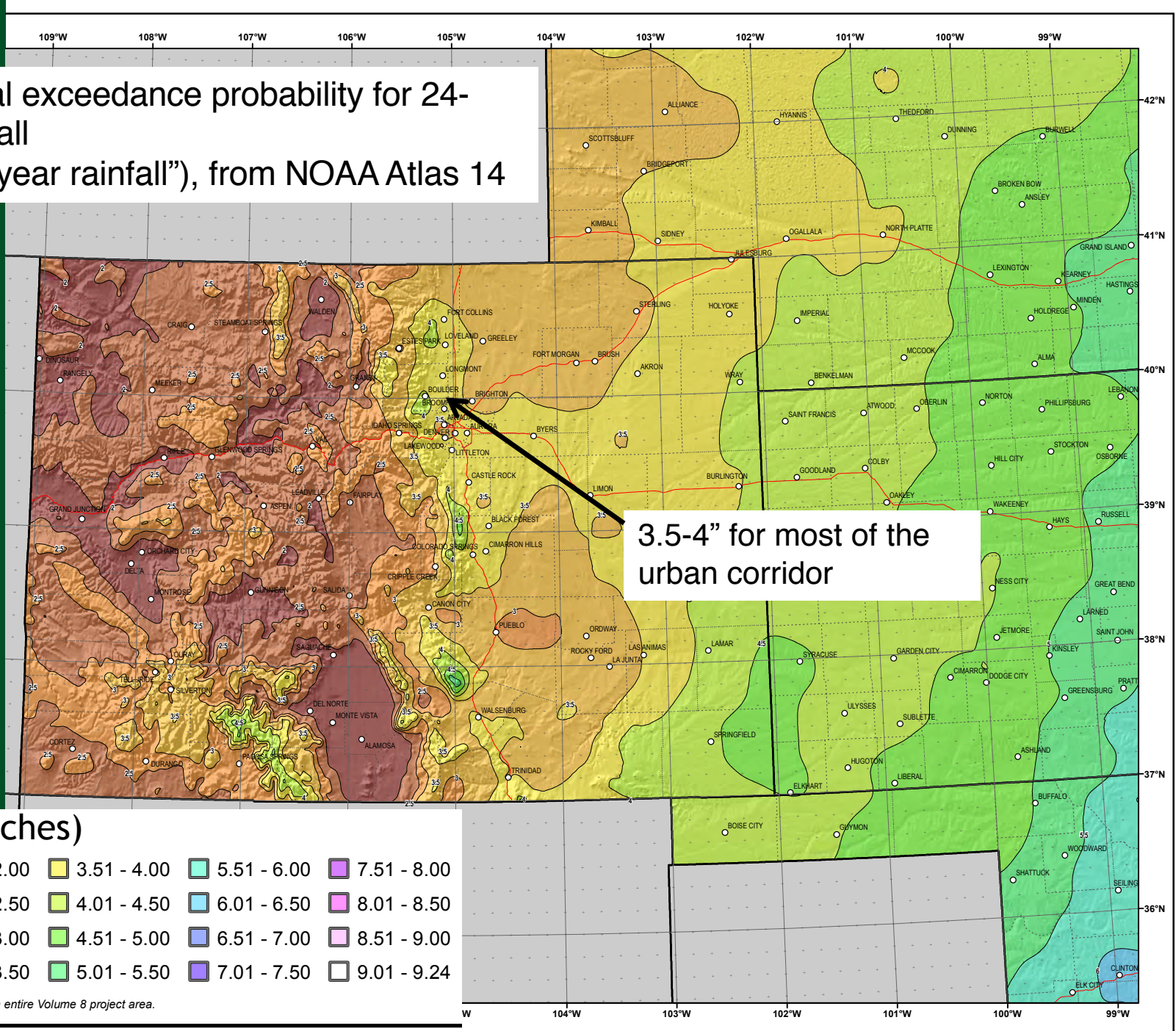
# How often does heavy rain fall?

- Using past rainfall data and statistical techniques, it's possible to estimate an “annual exceedance probability” for a given rainfall duration at a location
- For example, you could find the 24-hr rain amount that has a 10% probability of happening in any year
  - This is sometimes referred to as a “10-year rainfall”, though that terminology can be confusing
- These calculations are subject to big uncertainties for low probabilities, since the data record doesn't go back forever



Example from a station in Florida, from NOAA Atlas 14, volume 9

4% annual exceedance probability for 24-hour rainfall  
(i.e., “25-year rainfall”), from NOAA Atlas 14



3.5-4" for most of the urban corridor

(Inches)

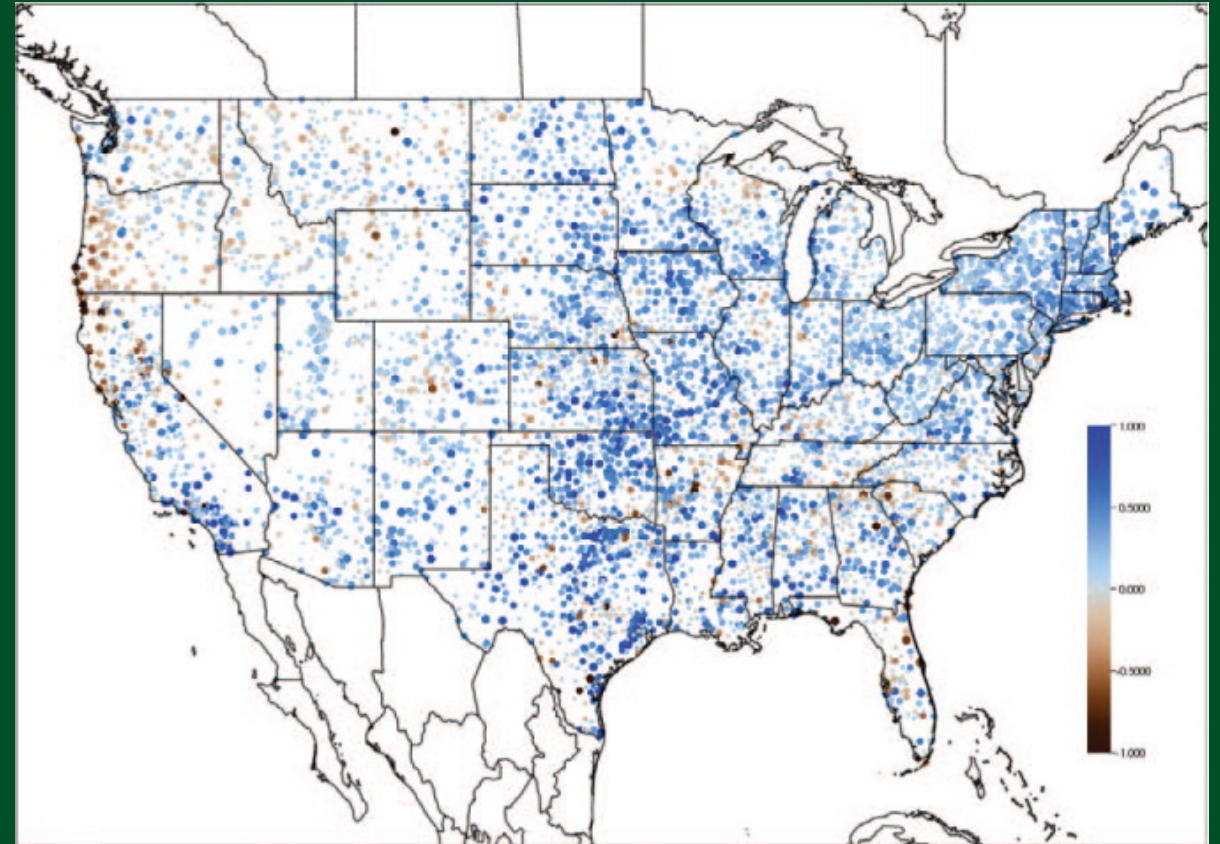
1.52 - 2.00	3.51 - 4.00	5.51 - 6.00	7.51 - 8.00
2.01 - 2.50	4.01 - 4.50	6.01 - 6.50	8.01 - 8.50
2.51 - 3.00	4.51 - 5.00	6.51 - 7.00	8.51 - 9.00
3.01 - 3.50	5.01 - 5.50	7.01 - 7.50	9.01 - 9.24

Legend based on entire Volume 8 project area.

# Trends for extreme rainfall in US

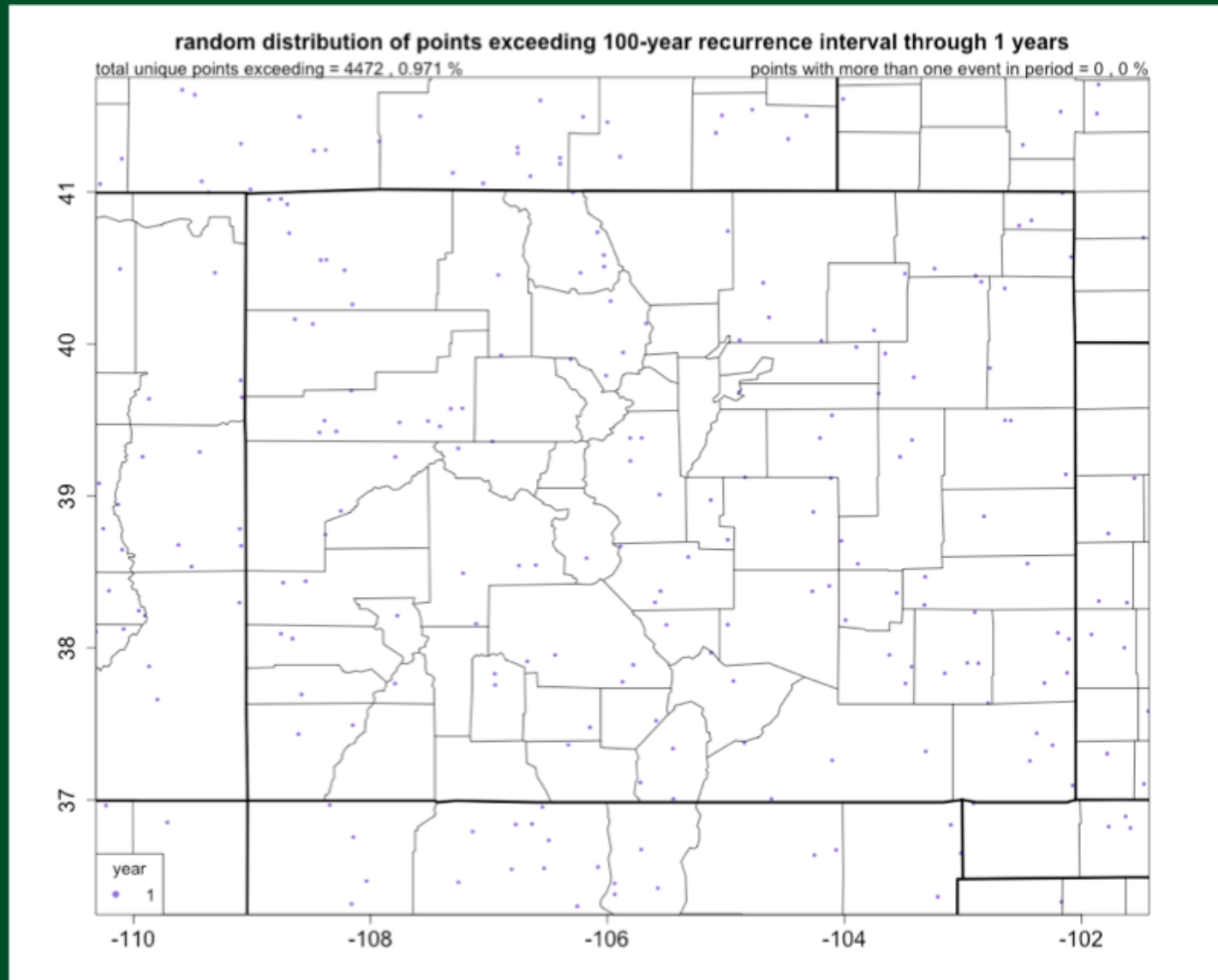
From Kunkel et al. (2013, *BAMS*)

- Heavy rainfall is becoming more frequent in many parts of the US, especially the Great Plains and Northeast...not so much in Colorado
- When aggregating over Colorado, no significant observed trends in heavy precipitation



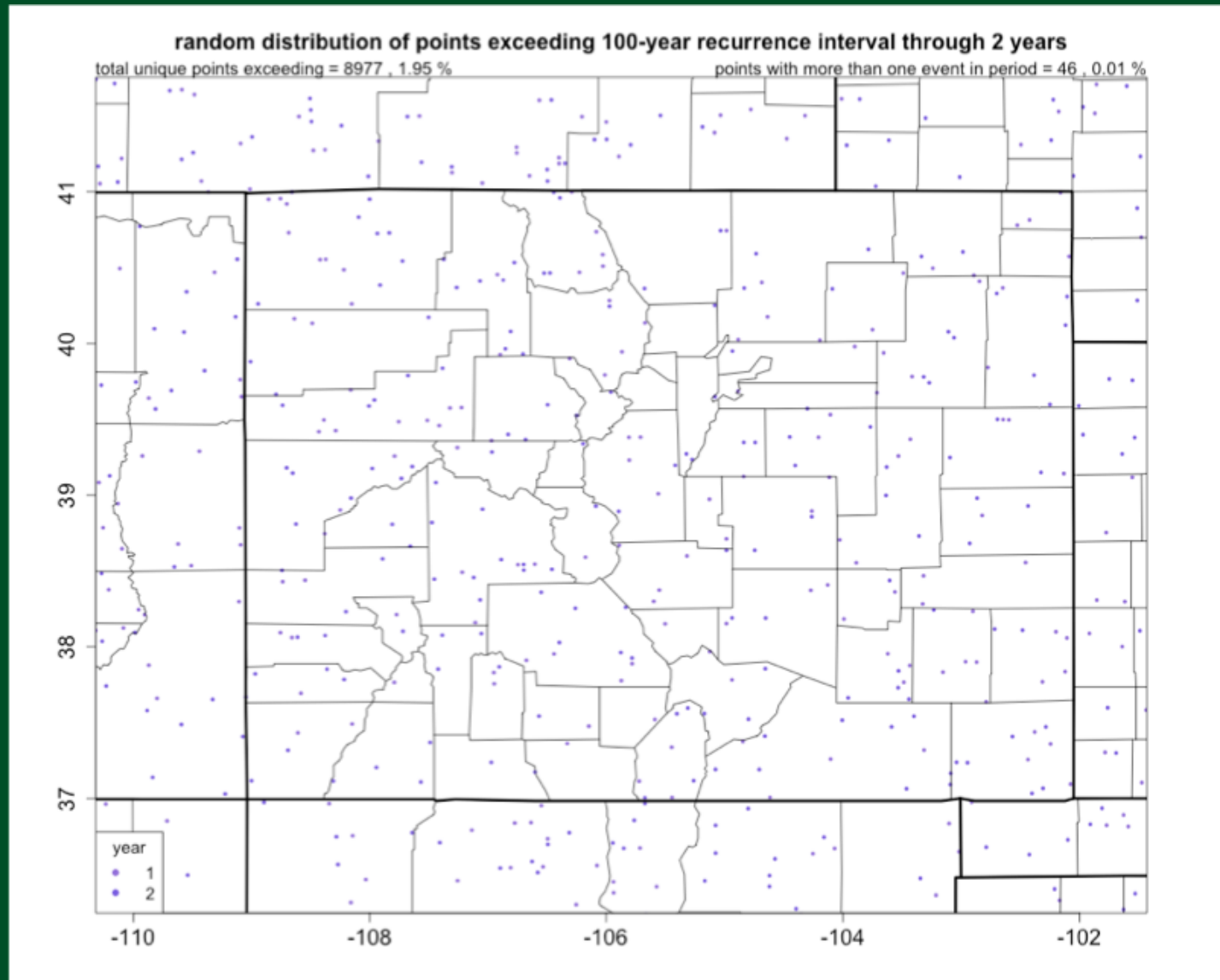
Changes in the “20-year rain event” over 1948-2010 (inches)  
Blue colors indicate that the 20-year rain event has become wetter, or in other words, a given amount of rainfall occurs more frequently now than it did in the past

# What if we had a random scattering of “100-year rain events” ?



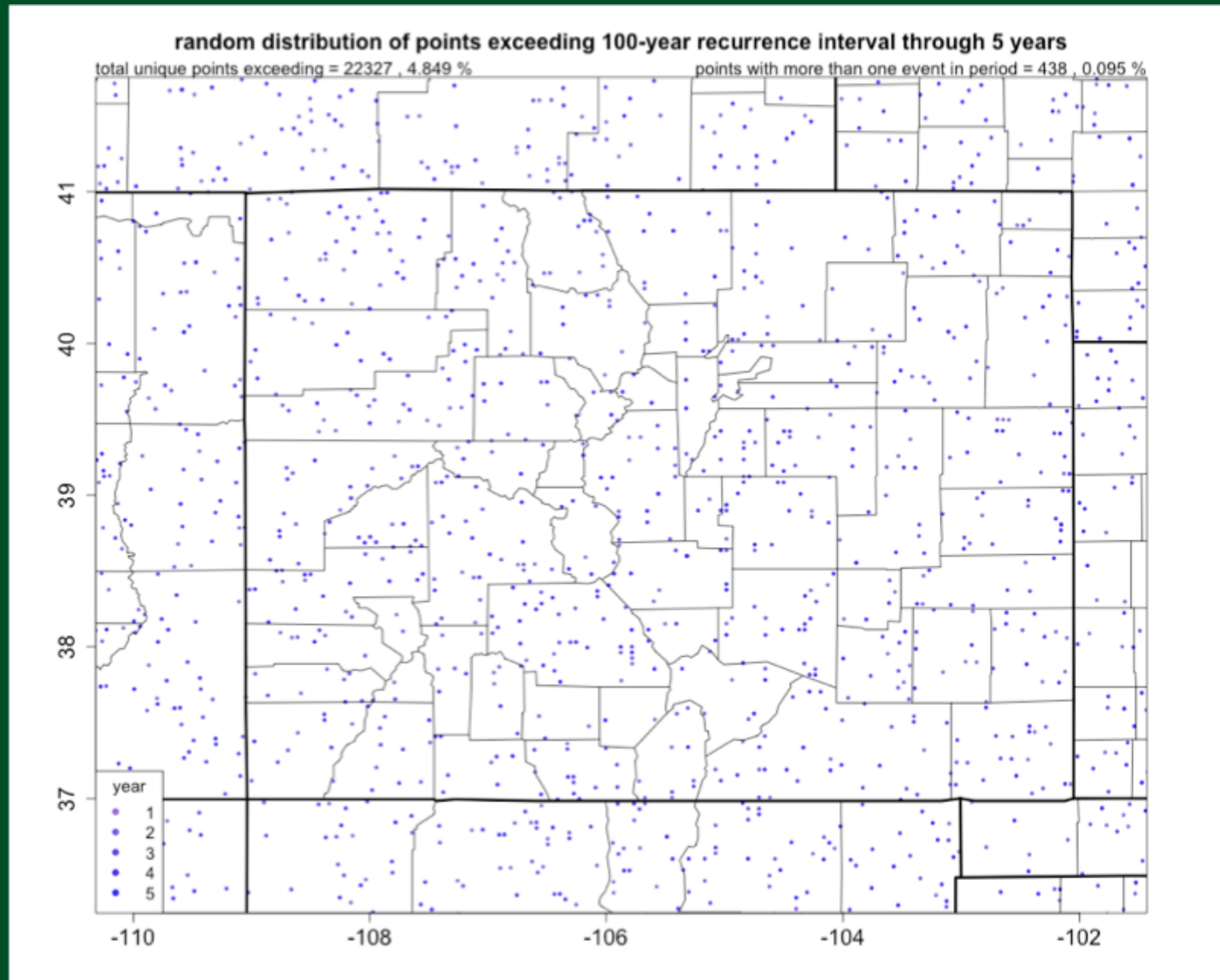
After 1 year:  
263 “100-year  
rainstorms” on this  
map

# What if we had a random scattering of “100-year rain events” ?



After 2 years

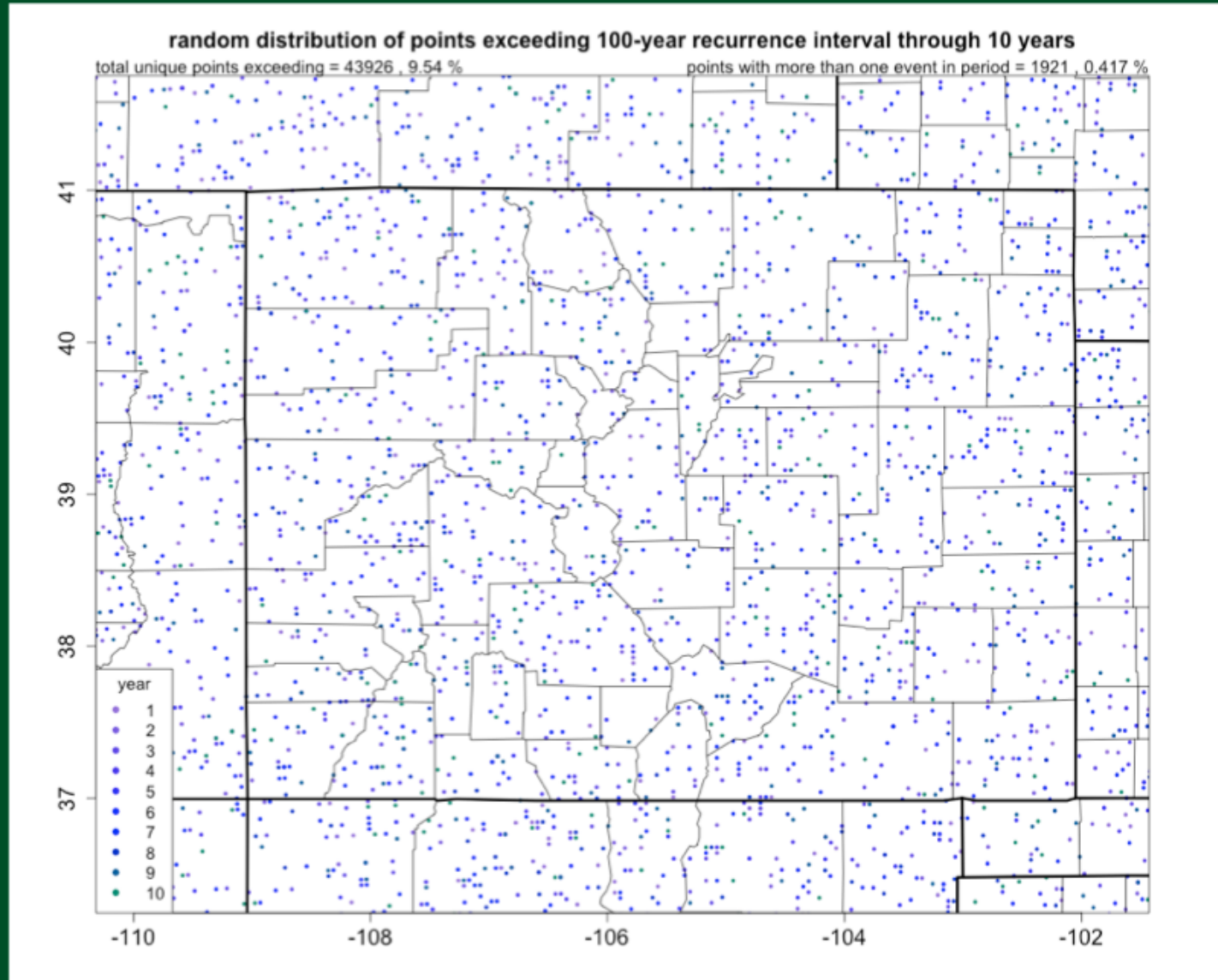
# What if we had a random scattering of “100-year rain events” ?



After 5 years

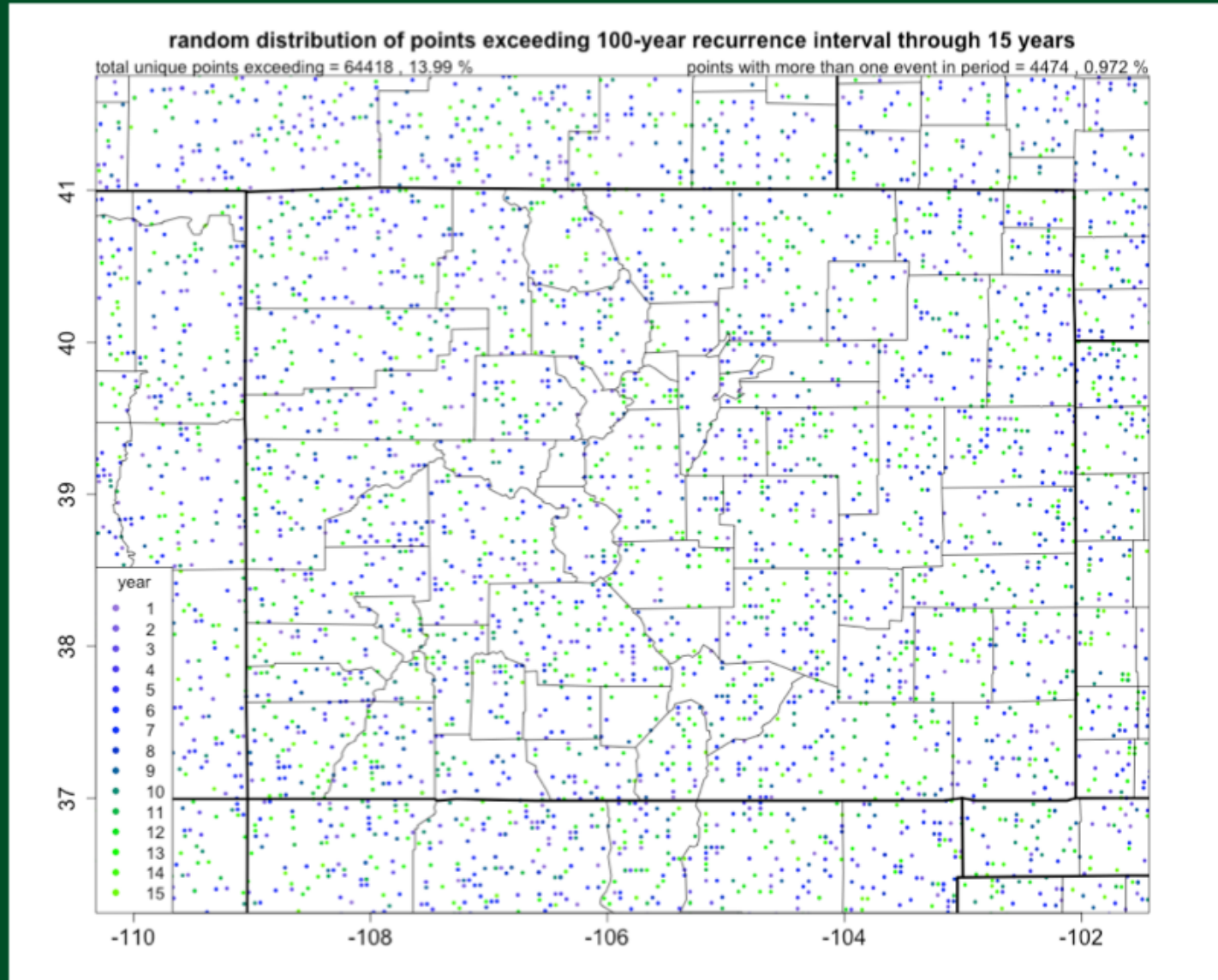


# What if we had a random scattering of “100-year rain events” ?



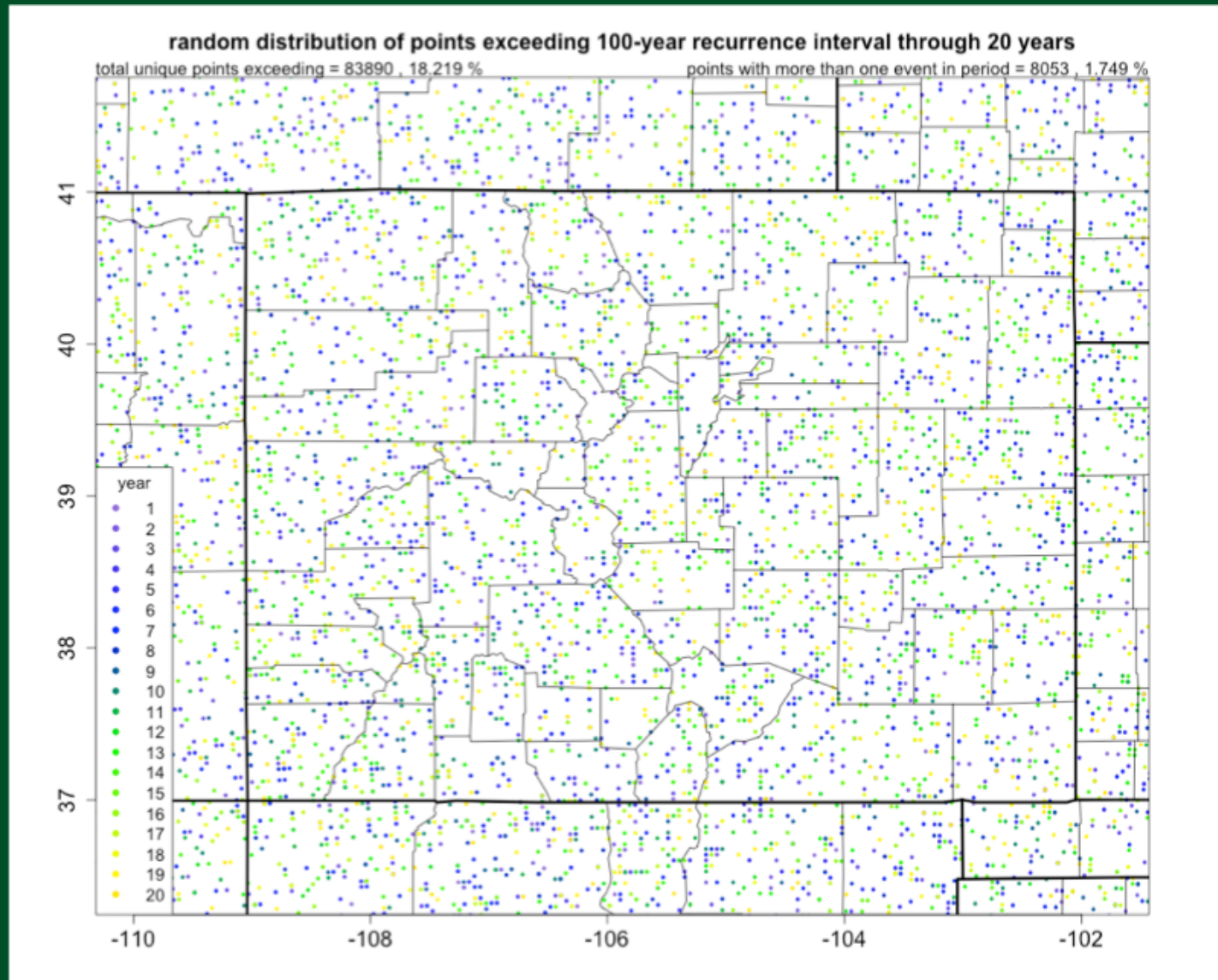
After 10 years

# What if we had a random scattering of “100-year rain events” ?



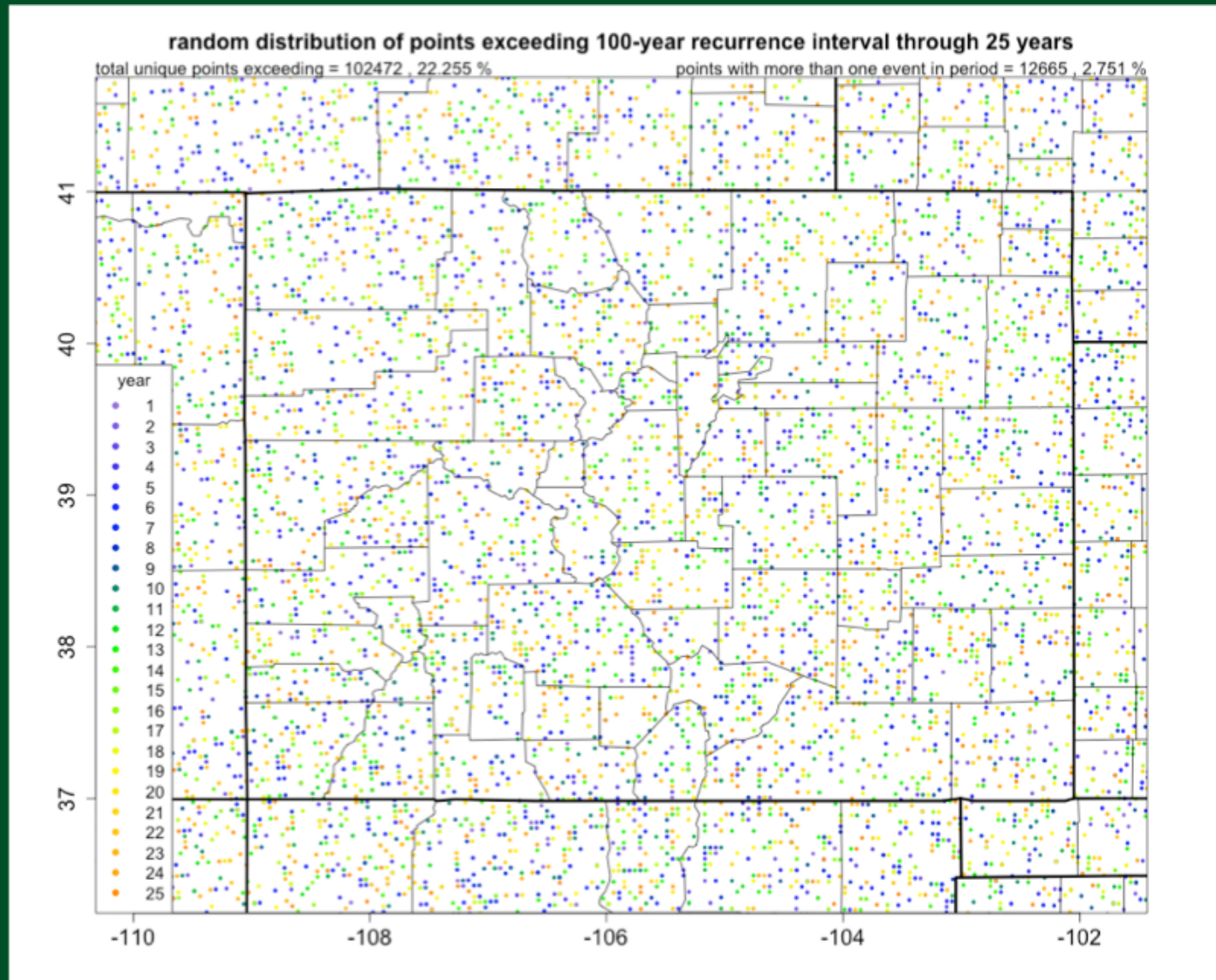
After 15 years

# What if we had a random scattering of “100-year rain events” ?



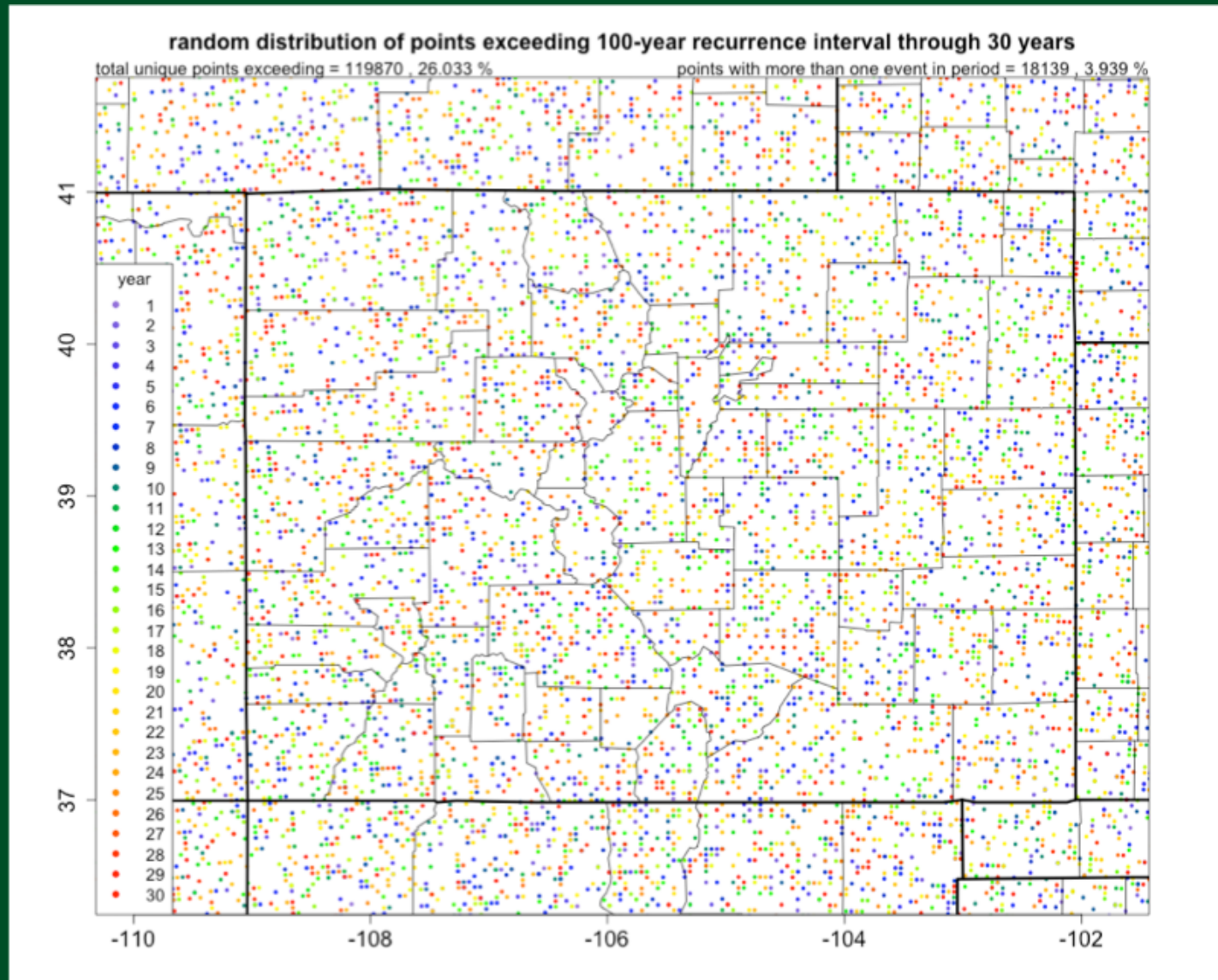
After 20 years

# What if we had a random scattering of “100-year rain events” ?



After 25 years

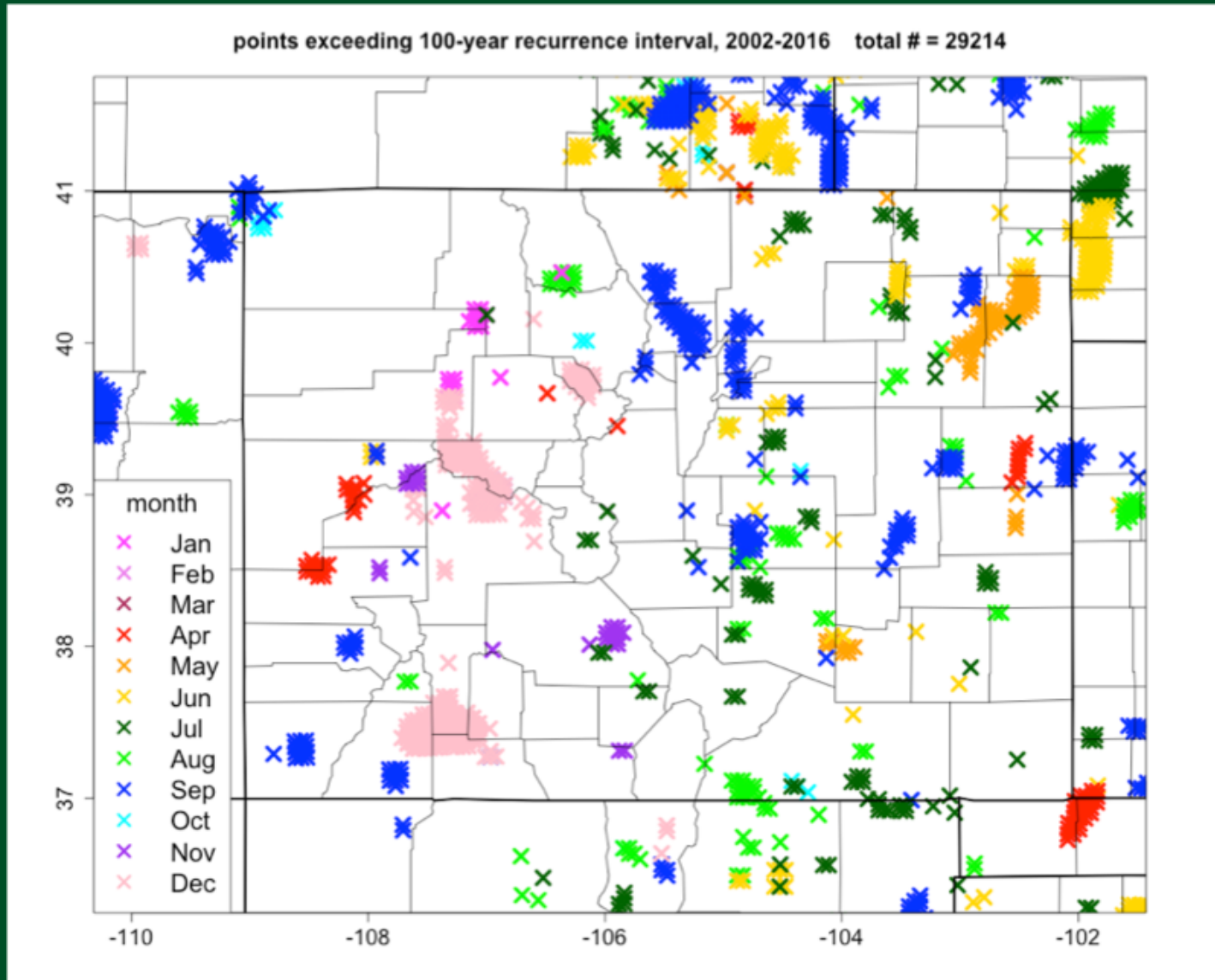
# What if we had a random scattering of “100-year rain events” ?



**After 30 years,  
each point has a  
26% chance of  
seeing a 100-year  
rain event!**

**And a 4% chance  
of getting more  
than one of them!**

# Actual “100-year rain events”, 2002-2016



Data: NOAA  
Stage IV analysis

Points exceeding  
the 100-year  
recurrence  
threshold for 24-hr  
rainfall

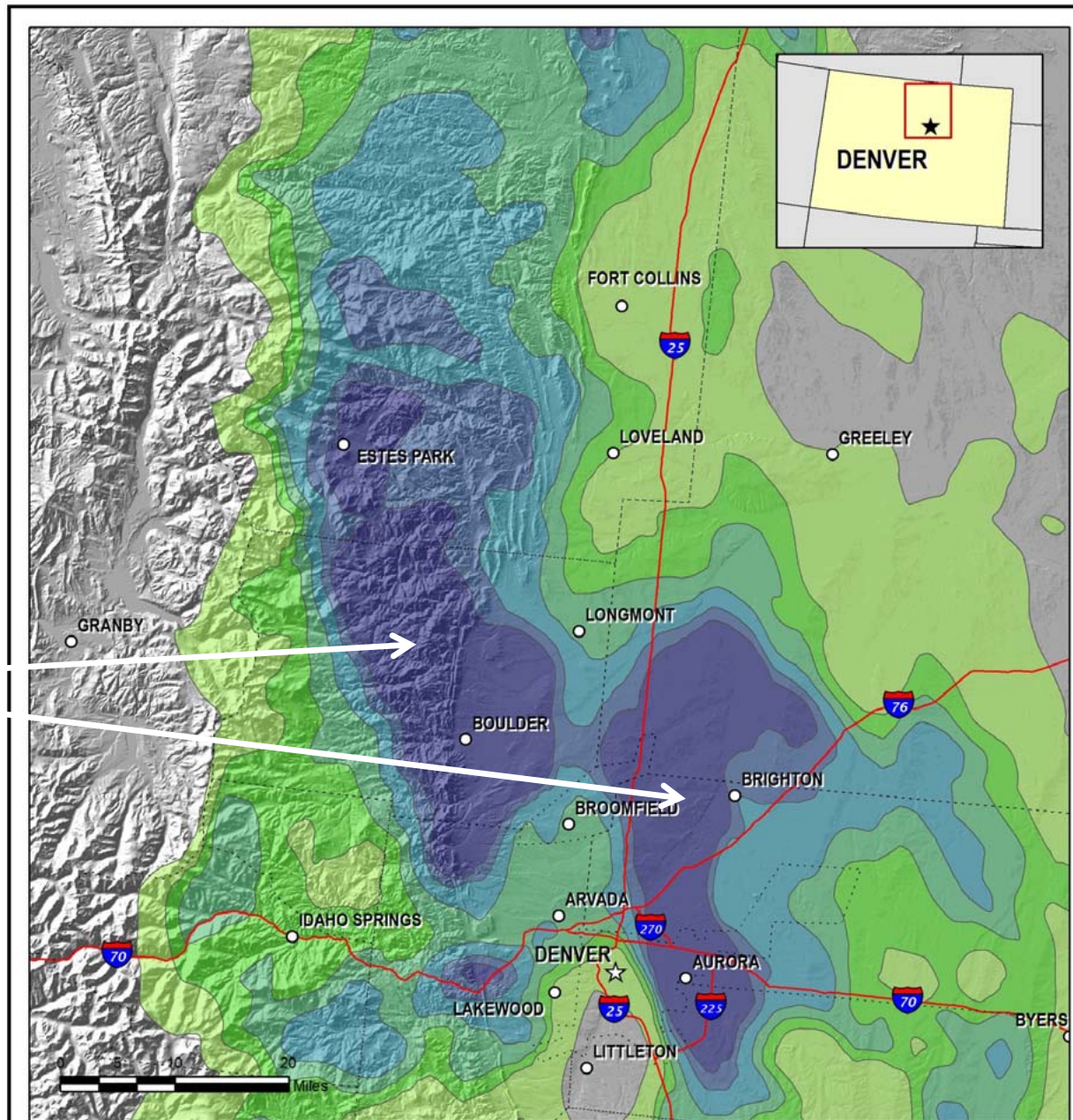
Some of these  
events you probably  
remember (Sept  
2013), but most you  
probably don't

This is because  
“unusual” rain  
doesn't always result  
in “unusual”  
flooding

# Exceedance probabilities for 7-day rainfall based on NOAA Atlas 14

Areas with  $\leq 0.01\%$  probability (i.e., a “1000-year rainfall”)

- $> 1/10$
- $1/50 - 1/10$
- $1/100 - 1/50$
- $1/200 - 1/100$
- $1/500 - 1/200$
- $1/1000 - 1/500$
- $< 1/1000$



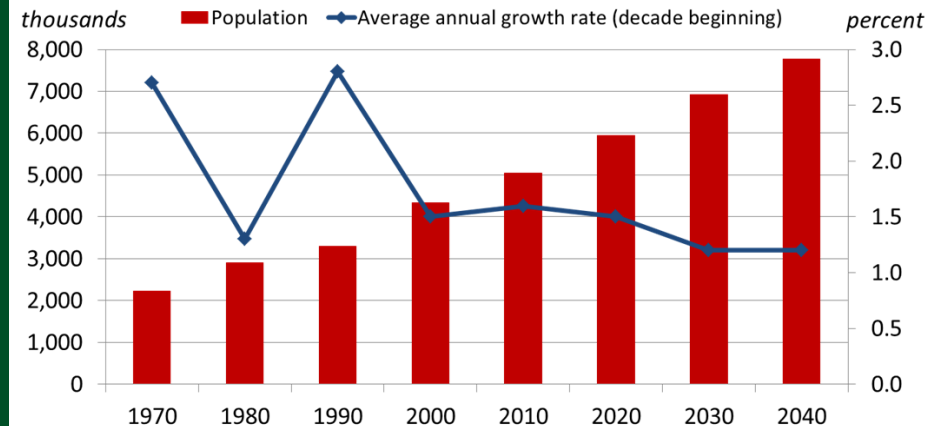
# What to expect in the future?

- As the climate continues to warm, more days with very high moisture values will occur
  - But will those translate into actual extreme rain events? Recall that moisture is only one ingredient
- Most indications are that heavy rain will become more likely
  - But will that be true over Colorado? Not yet clear.
- **Even with these uncertainties, do we feel well prepared for even \*today's\* extreme rainfall and flooding?**
- And what if we add 2-3 million more people (and associated infrastructure), many of them along the flood-vulnerable Front Range?

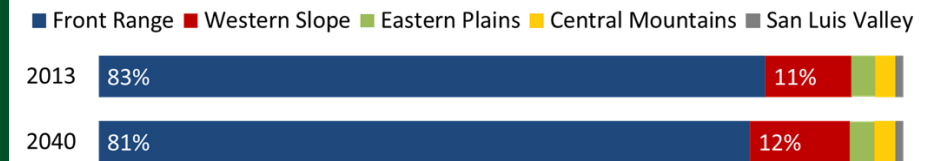
## COLORADO POPULATION 1970-2040

Slower growth, rapid aging, and increased diversity

Colorado's population was just over 5 million in 2010. Growth rates are expected to decline slowly over the next few decades to reach just under 8 million by 2040.



Growth rates vary significantly across Colorado. The majority of Coloradans are expected to continue to reside along the front range.



<https://demography.dola.colorado.gov/demography/infographics/#infographics>



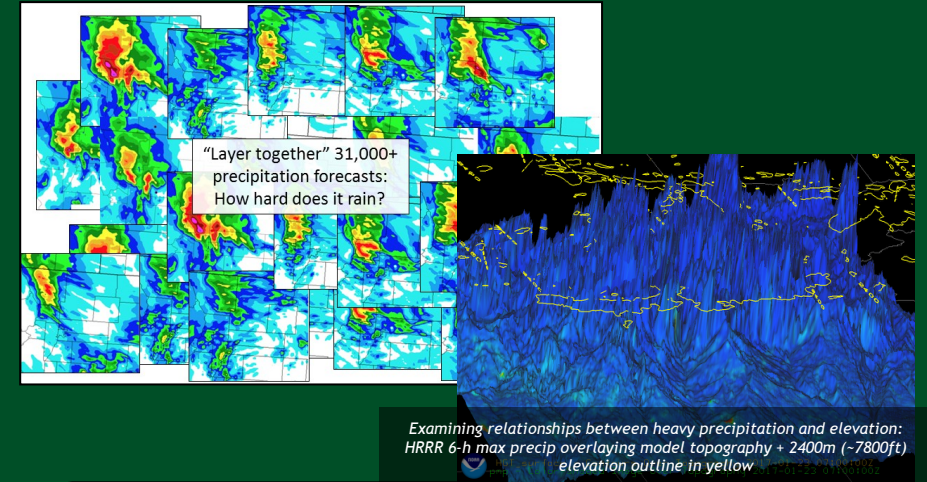
# Ongoing study to update “probable maximum precipitation” in Colorado and New Mexico for dam safety

Colorado and New Mexico have sponsored a study to update precipitation frequency estimates for dam safety purposes

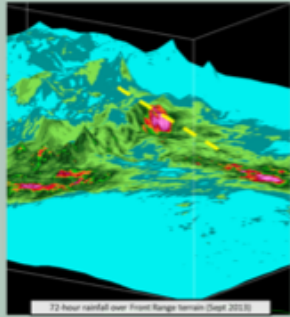
- Task 1 (Applied Weather Associates) updating conventional deterministic “storm-based” methods.
- Task 2 (Extreme Precipitation Group, MetStat) developing a risk-based (probabilistic) regional precipitation frequency estimation tool to enable annual exceedance estimates of Task 1 results.
- Task 3 (NOAA Earth System Research Laboratory) includes a proof-of-concept scope utilizing NOAA’s state-of-the-art High Resolution Rapid Refresh (HRRR) physically-based dynamical weather prediction model.

**Lots of collaboration between state, federal, and private sectors! Look for a final report in ~June 2018.**

(info from Kelly Mahoney, NOAA and Bill McCormick, DWR)



**Why is dynamical modeling a potentially desirable approach to PMP estimation?**

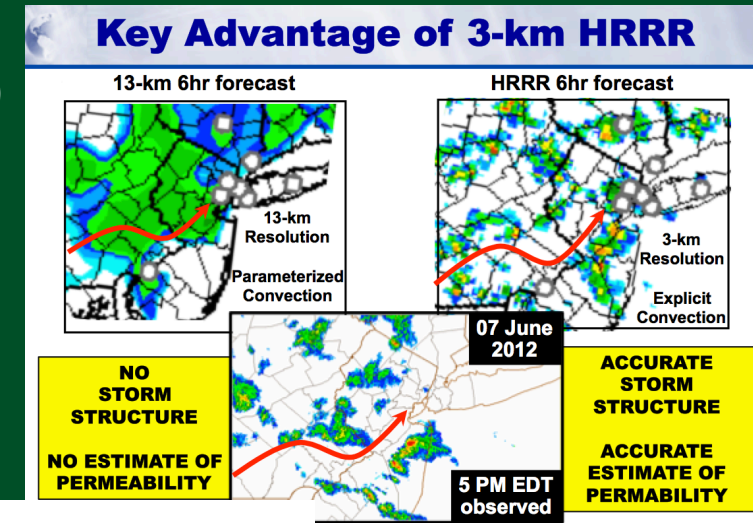


- Scientific understanding of physical processes responsible for extreme storms enhanced since older guiding documents (e.g., NOAA HMR’s) were created
- Dynamical models solve physical equations of atmosphere: generate precipitation according to “real-world” environment, with continuity in space and time
  - Reduces need for many spatial, temporal, physical assumptions (e.g., storm transposition, storm templates, moisture maximization, etc.)
  - Especially useful in data-sparse regions of complex (& high-elevation) topography
  - Straightforward methods available for quantification of uncertainty

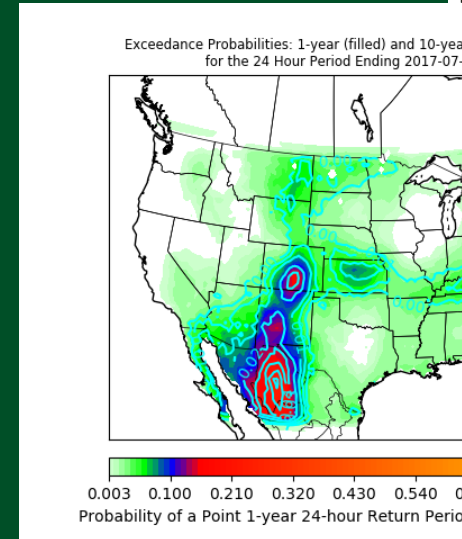
# Forecasting advances

- Rainfall – and especially heavy rainfall – remains very difficult to predict
- But some major advances have been taking place: models with better resolution, “ensembles” of models, statistical processing of model forecasts, flood forecasts, etc.
- Expect rainfall forecasts to get better – but don’t expect to know whether it’ll rain on your house but not your neighbor’s!

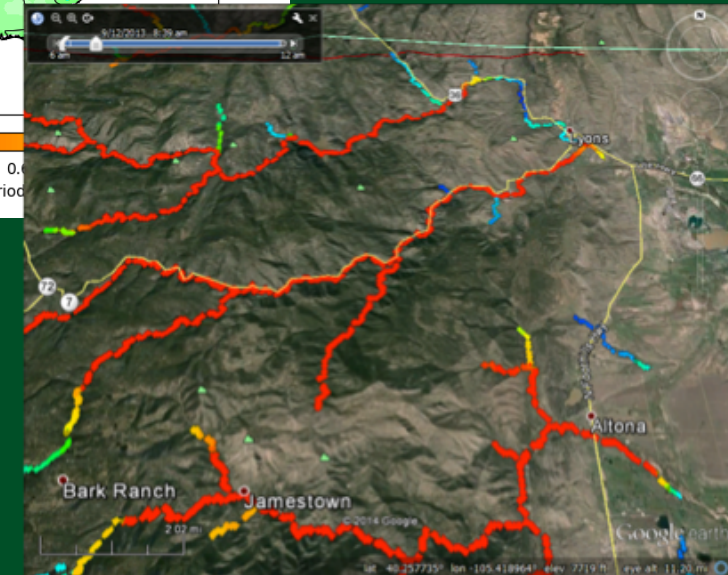
(NOAA)



(CSU)

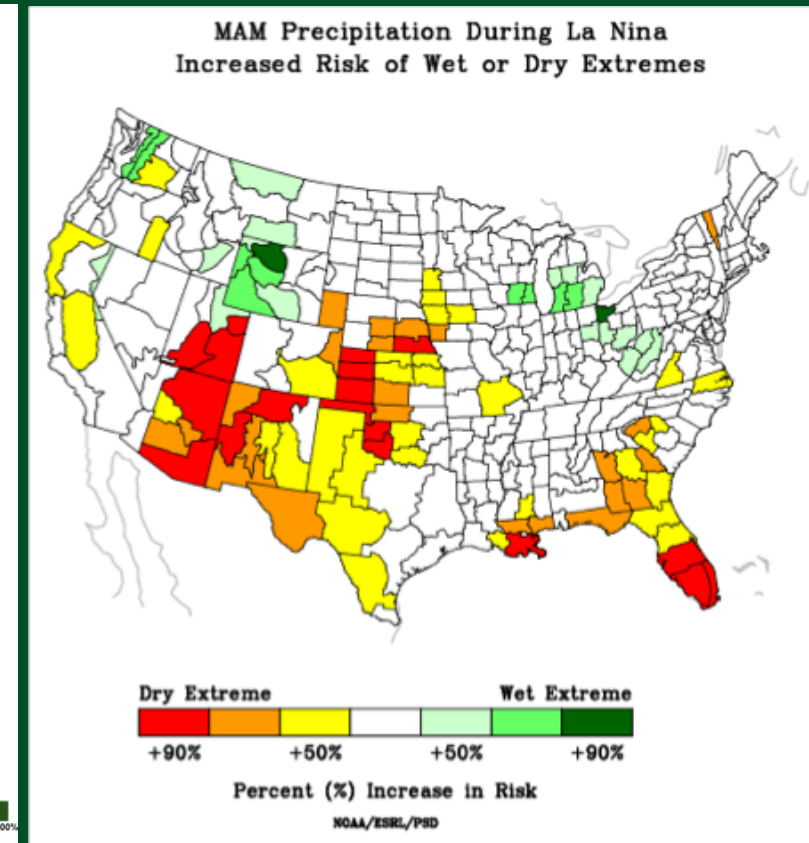
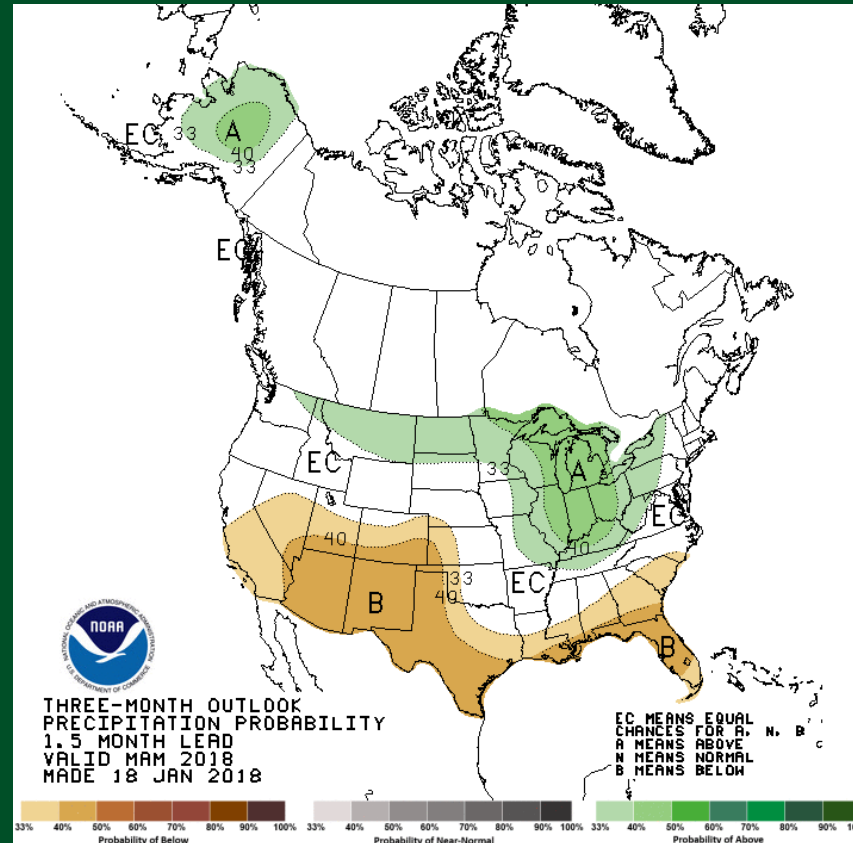


(NCAR)



# Outlook for precip (and extreme events?) in relation to La Nina

- We're currently in La Niña conditions – cool water in the eastern Pacific Ocean
- This tends to divide the state, with near, or slightly wetter than normal in the north, and dry in the south
- Outlooks show an increased chance of a dry spring
- But there is at least some precedent for wet spring following a La Niña winter (April 1999 as one example)



**Orchard Mesa** meta

Station ID: ORM01 Lat: 39.0420 Lon: -108.4600 Elev: 4600 ft

Latest

Historical

Photos

**26°F**

0.00 in

63%

1.7 mph

Vapor Pressure: 0.30 kPa

Solar Radiation: 0.0 kJ/m<sup>2</sup>·min

Updated January 16th 2018, 9:00 pm

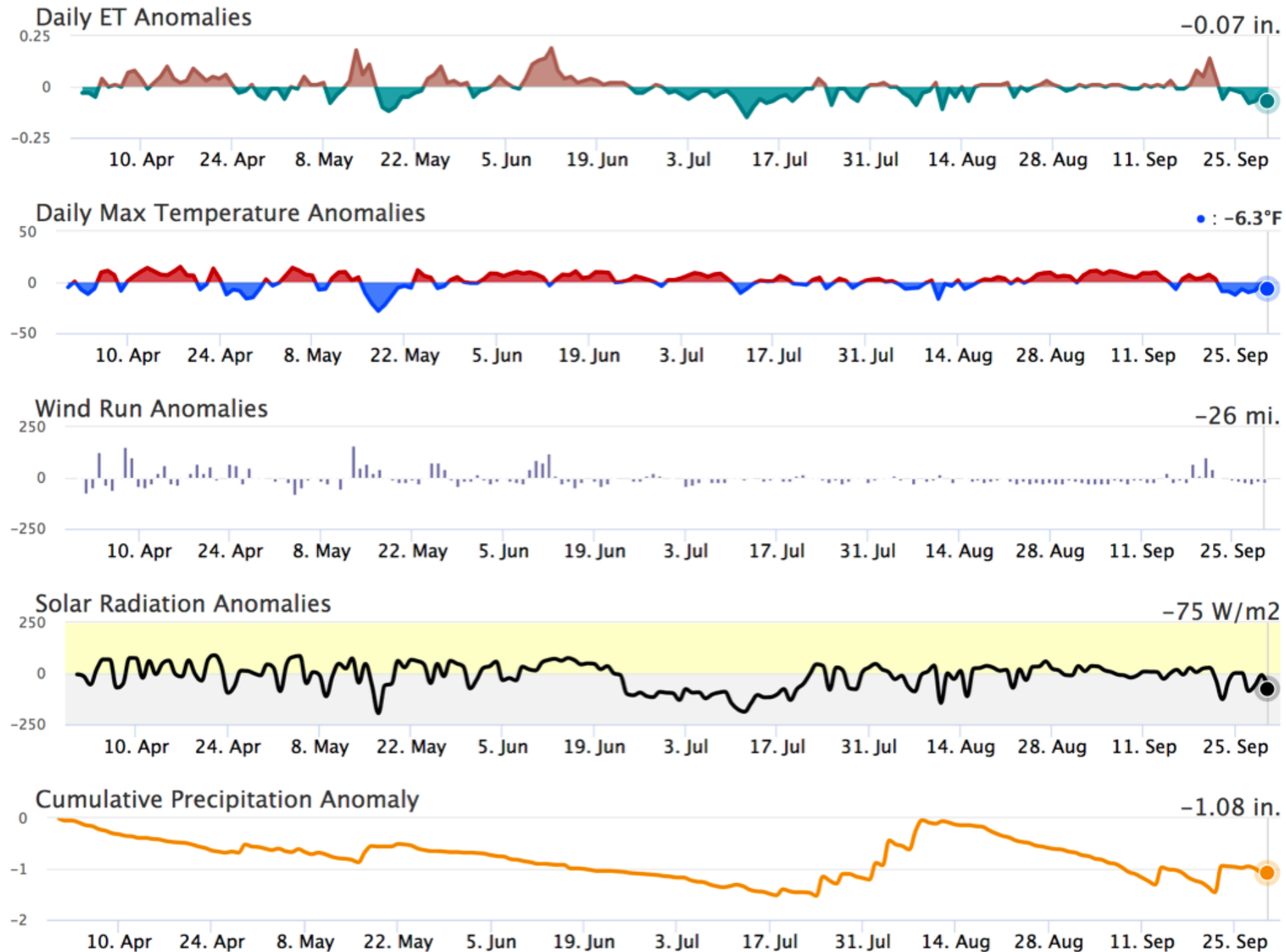


# CoAgMET

- ❑ 75 stations
- ❑ 10 proposed for west slope
- ❑ 44 5-minute stations
- ❑ interactive mapping through eRAMS
- ❑ includes
  - ❑ time series charts
  - ❑ site photos

[coagmet.colostate.edu](http://coagmet.colostate.edu)

# Growing season summaries at long-term stations: Olathe (2017)



[http://climate.colostate.edu/2017ET/et\\_summary\\_oth\\_anom.html](http://climate.colostate.edu/2017ET/et_summary_oth_anom.html)

**And finally, the all-important  
question:  
“Do you have a rain gauge?”**



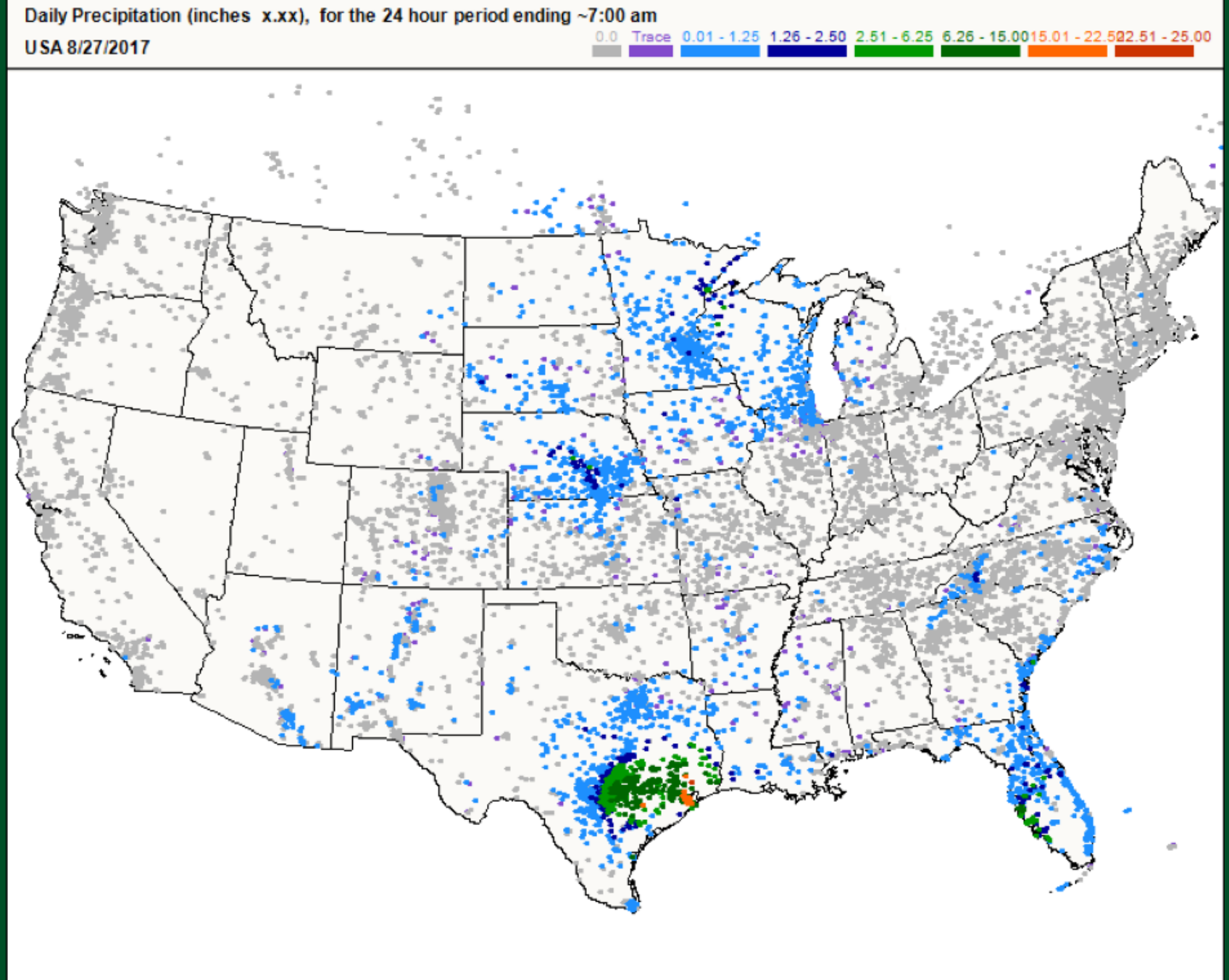


**If you are interested in weather and the variations in precipitation, please join the Community Collaborative Rain, Hail and Snow Network**

**<http://www.cocorahhs.org>**

**or see me today**

# CoCoRaHS data in Hurricane Harvey, August 2017





Thank you for the opportunity to be here!

<http://climate.colostate.edu/>

[russ.schumacher@colostate.edu](mailto:russ.schumacher@colostate.edu)

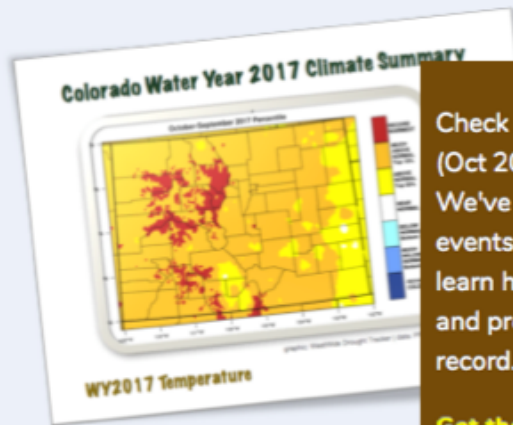


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# Backup slides

- General Info ▾
- Colorado's Climate ▾
- Data Access
- Climate Maps
- Normals and Extremes ▾
- Drought ▾
- Tools ▾



Check out our Water Year summary (Oct 2016 - Sep 2017) for Colorado. We've compiled a list of significant events and water year records. Also learn how our water year temperature and precipitation ranks in the historic record.

**Get the 2017 Water Year Report!**

Previous | Next

**Current Conditions**

**Fort Collins, CO**

**33.8°F**

Last Updated on November 8, 5:25 PM MST

Wind: Calm  
Dewpoint: 33°F  
Humidity: 98%

Zip Code Local Conditions

**News Feeds**

**Colorado Climate Ce...**  
Liked 738 likes

**Colorado Climate Center** 7 hours ago

Fog along the Front Range this morning - check out this magical time-lapse looking south over Lyons. Colorado:

## new website features at [climate.colostate.edu](http://climate.colostate.edu)

- Data Access
- Climate Maps (coming soon)
- Climate Normals
- Climate Extremes
- Tools

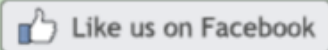




# INTERMOUNTAIN WEST DROUGHT EARLY WARNING SYSTEM



## WEBINAR SPONSORS



Join Our Mailing List!

[US Drought Monitor](#)

Greetings,

Please join us tomorrow morning, **Tuesday, January 16th at 10:00AM MST** for our monthly "Climate, Water and Drought Assessment" Webinar.

To register go to the Colorado Climate Center website at: [http://climate.colostate.edu/webinar\\_registration.html](http://climate.colostate.edu/webinar_registration.html).

A toll-free 800 number is provided for calling-in. Our webinars are brief (usually less than 30 minutes) and provide updated information assessing climate, water and drought for the Intermountain West.

Intermountain West Drought Early Warning System Webinars are being brought to you by the Colorado Climate Center at Colorado State University with support from the National Integrated Drought Information System (NIDIS). For more information on NIDIS please visit: <https://www.drought.gov/drought/what-nidis>

Sincerely,

The Colorado Climate Center Team

# Intermountain West drought early warning system

We lead monthly webinars on the drought situation in the intermountain west (might become every 2 weeks if drought worsens)

Register at [http://climate.colostate.edu/webinar\\_registration.html](http://climate.colostate.edu/webinar_registration.html)

See graphics at <http://climate.colostate.edu/~drought/>

