Droughts, Floods, and Wildfire

Chapter 8: Climate Science Special Report
4th US National Climate Assessment, Vol. 1

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Photo credit: National Park Service

US DOE Policy 411.2A

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Types of drought

A hierarchy of drought definitions:

- Meteorological drought → precipitation deficit.
- Agricultural drought → soil moisture deficit.
- Hydrological drought → runoff deficit
- Socioeconomic drought → demand exceeds supply

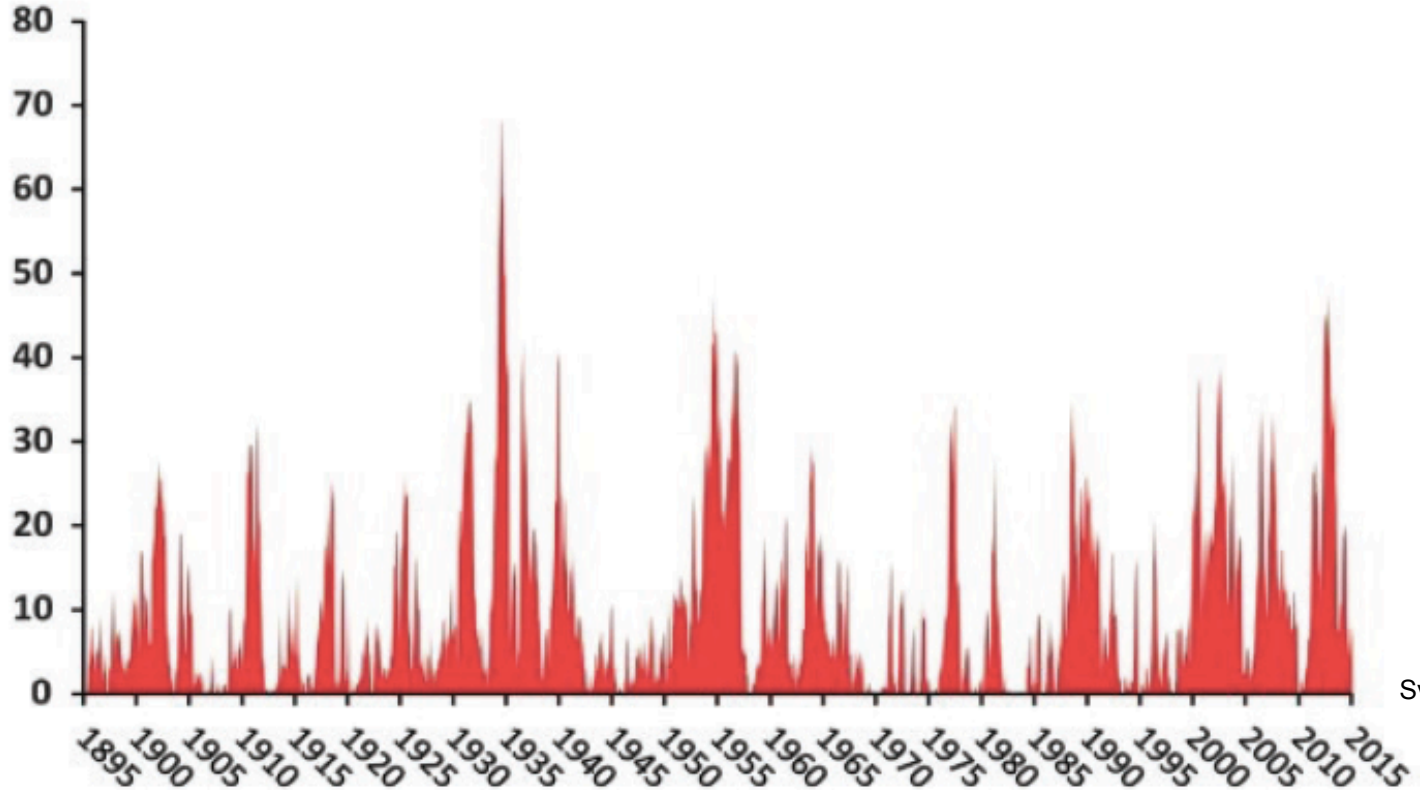
https://www.ncdc.noaa.gov/monitoring-references/dyk/drought-definition

Key message #1

Recent droughts and associated heat waves have reached record intensity in some regions of the United States; however, by geographical scale and duration, the Dust Bowl era of the 1930s remains the benchmark drought and extreme heat event in the historical record (*very high confidence*). While by some measures, drought has decreased over much of the continental United States in association with long-term increases in precipitation, neither the precipitation increases nor inferred drought decreases have been confidently attributed to anthropogenic forcing.

Percent Area of the United States in Severe to Extreme Drought

January 1895–February 2015



Svoboda et al. 2015

The report notes that the PDSI may not be suitable for climate change projections due to its simplified land surface model and the potential to be overly sensitive to temperature increases.

Key message #2 (part 1)

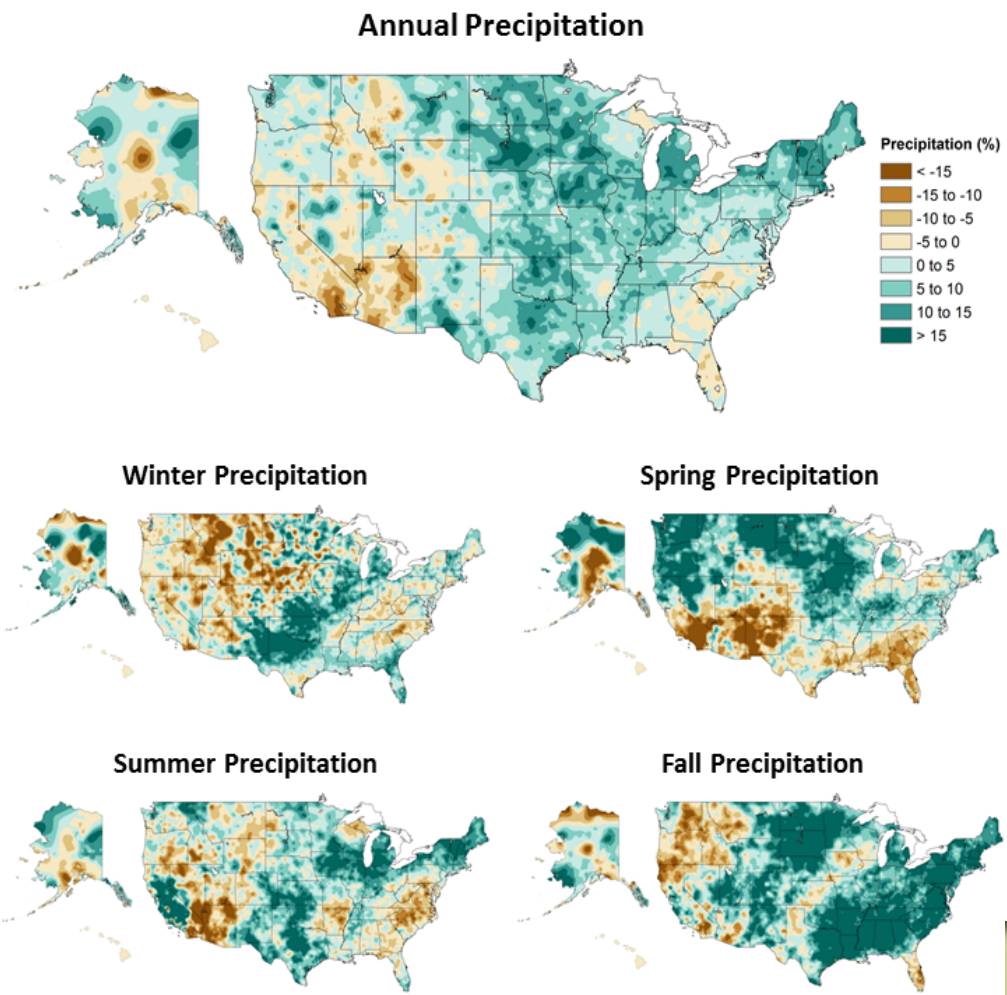
The human effect on recent major U.S. droughts is complicated. Little evidence is found for a human influence on observed precipitation deficits…

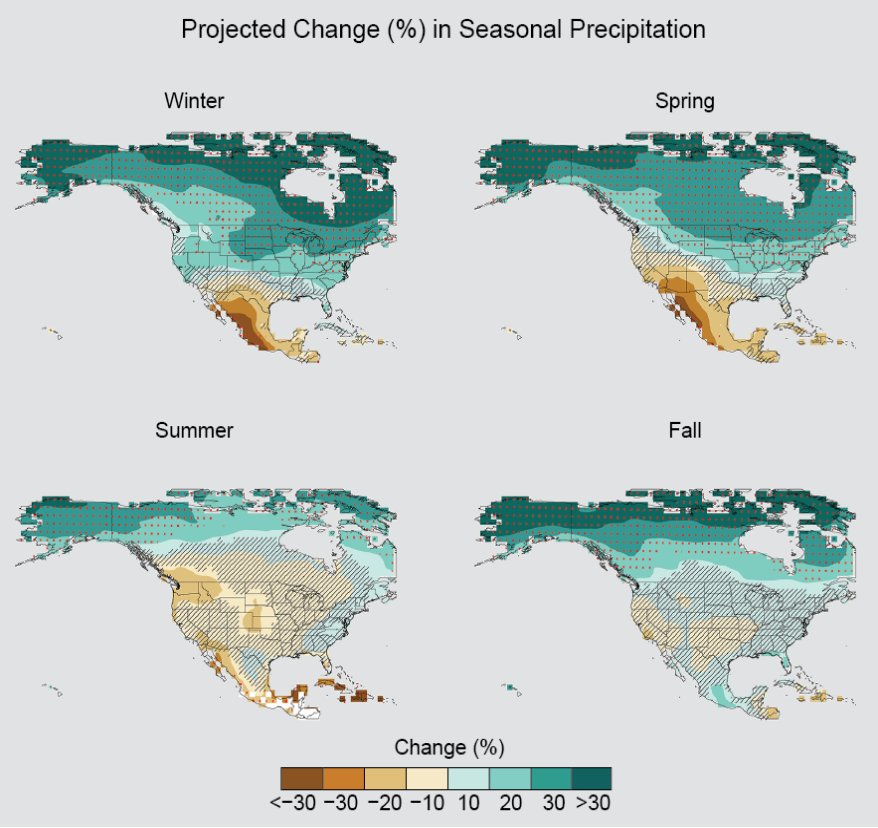
In other words, we do not attribute any **trends** in meteorological drought to a human influence.

Courtesy John Luker &California State Parks vie nps.gov

Precipitation changes

Observed changes





Projected future changes

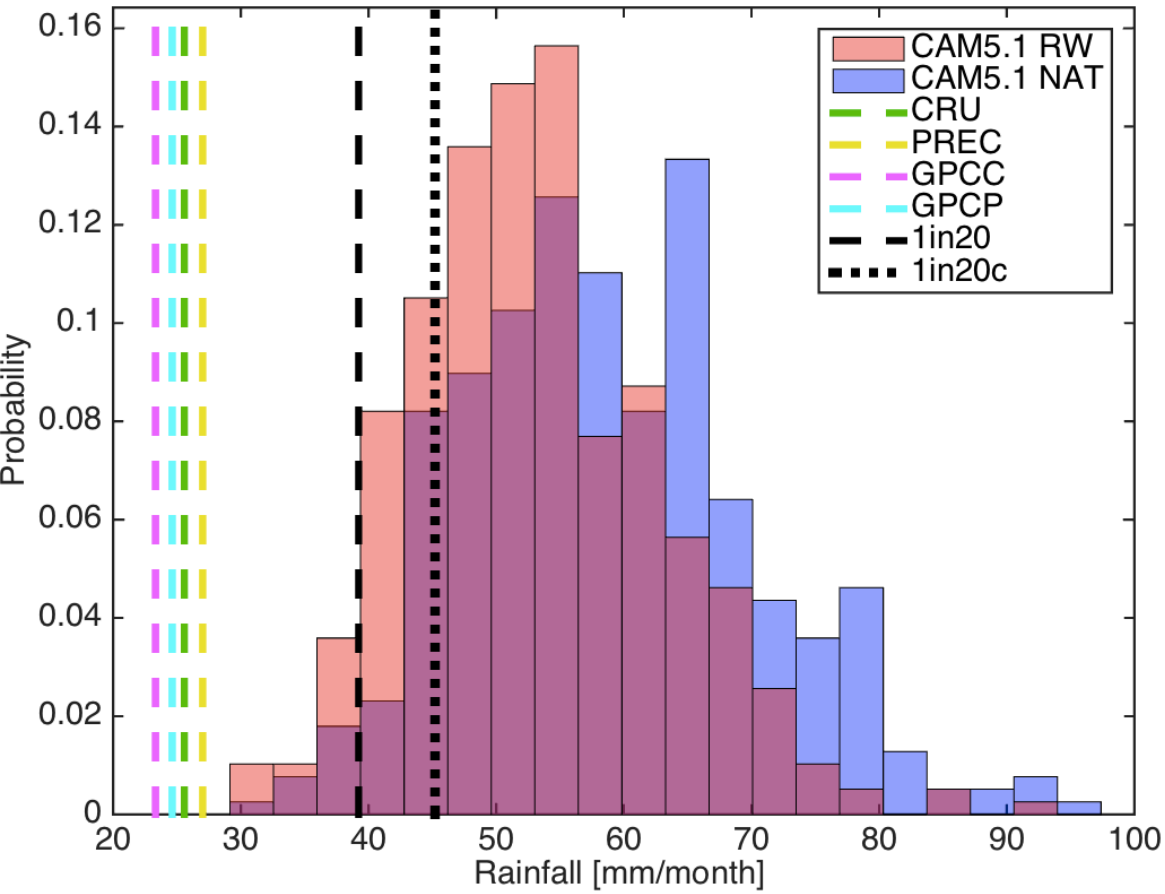
- Changes in precipitation are not attributable to human causes.
- Nor are any such decreases anticipated except in the Southwest during winter/spring.
- Large scale meteorological drought **trends** are not attributable in the US

Meteorologal drought attribution studies

Authors	Event Year and Duration	Region or State	Type	Attribution Statement
Rupp and Mote 2012 / Angélil et al. 2017	MAMJJA 2011	Texas	Meteorological	+/+
Hoerling et al. 2013	2012	Texas	Meteorological	+
Rupp et al. 2013 / Angélil et al. 2017	MAMJJA 2012	CO, NE, KS, OK, IA, MO, AR & IL	Meteorological	0/0
Rupp et al. 2013 / Angélil et al. 2017	MAM 2012	CO, NE, KS, OK, IA, MO, AR & IL	Meteorological	0/0
Rupp et al. 2013 / Angélil et al. 2017	JJA 2012	CO, NE, KS, OK, IA, MO, AR & IL	Meteorological	0/+
Hoerling et al. 2014	MJJA 2012	Great Plains/Midwest	Meteorological	0
Swain et al. 2014 / Angélil et al. 2017	ANN 2013	California	Meteorological	+/+
Wang and Schubert 2014 / Angélil et al. 2017	JS 2013	California	Meteorological	0/+
Knutson et al. 2014 / Angélil et al. 2017	ANN 2013	California	Meteorological	0/+
Knutson et al. 2014 / Angélil et al. 2017	MAM 2013	U.S. Southern Plains region	Meteorological	0/+

2011 MAMJJA Texas meteorological drought

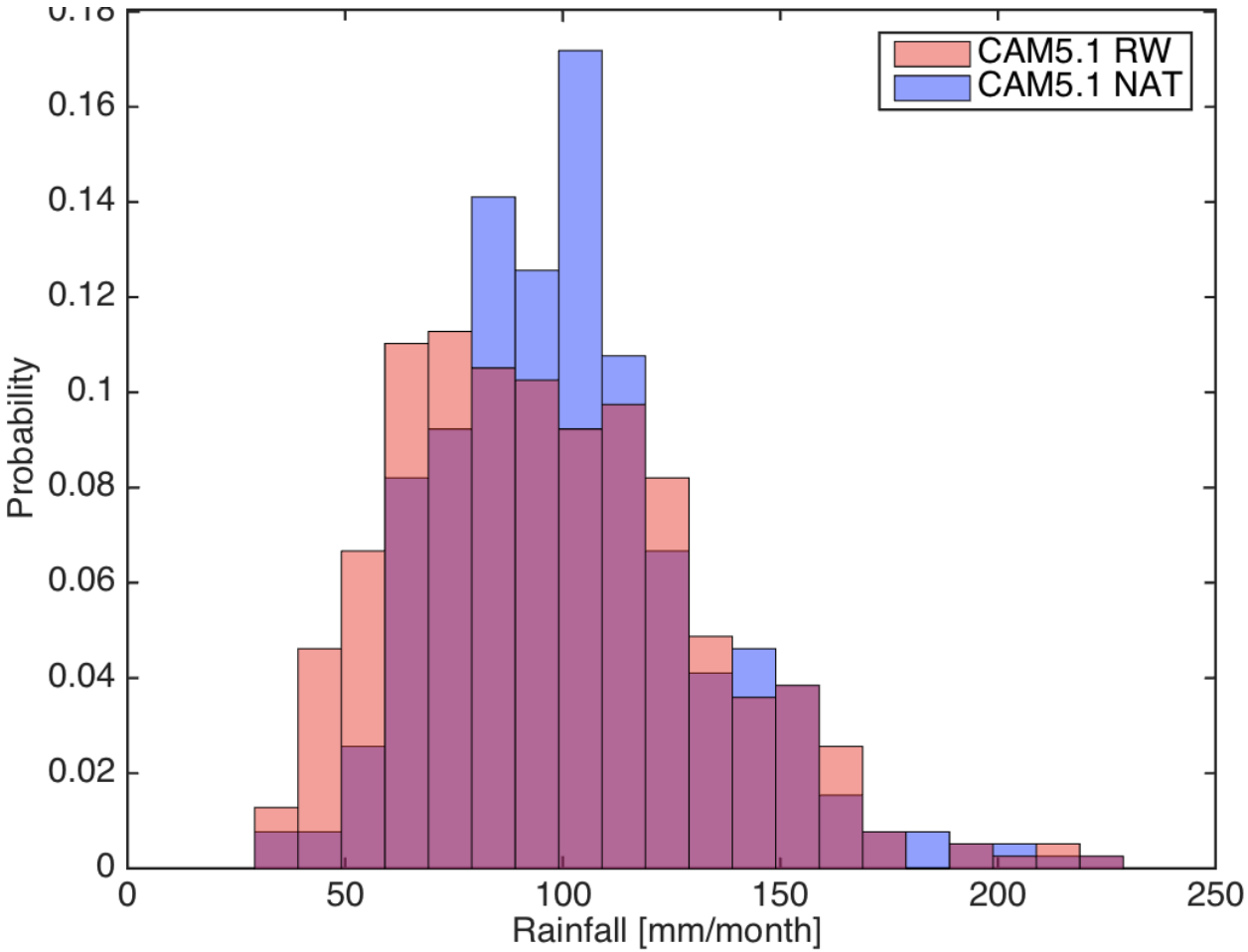
Oliver Angelil, Dáithí Stone, Michael Wehner, Christopher J. Paciorek, Harinarayan Krishnan, William Collins (2017) An independent assessment of anthropogenic attribution statements for recent extreme weather events. *Journal of Climate 30,* 5-16, DOI: 10.1175/JCLI-D-16-0077.1



- Model indicates an overall drying in this season in Texas.
- But this model would indicate that this is a very rare event. Return period >400 years.
- Two studies support attribution.
  - Attribution without detection.

California meteorological drought

- 4 studies find a human induced increase in the chances of a California precipitation deficit.
  - But 3 of those are Angelil et al.
- 2 studies find no human influence.



Key questions remain unanswered.

- A large part of the precipitation deficit was caused by the "ridiculously resilient ridge".
- Circulation anomalies are difficult to attribute.
- Uncertainties in attribution of any meteorological drought remain high.

Key message #2 (part 2)

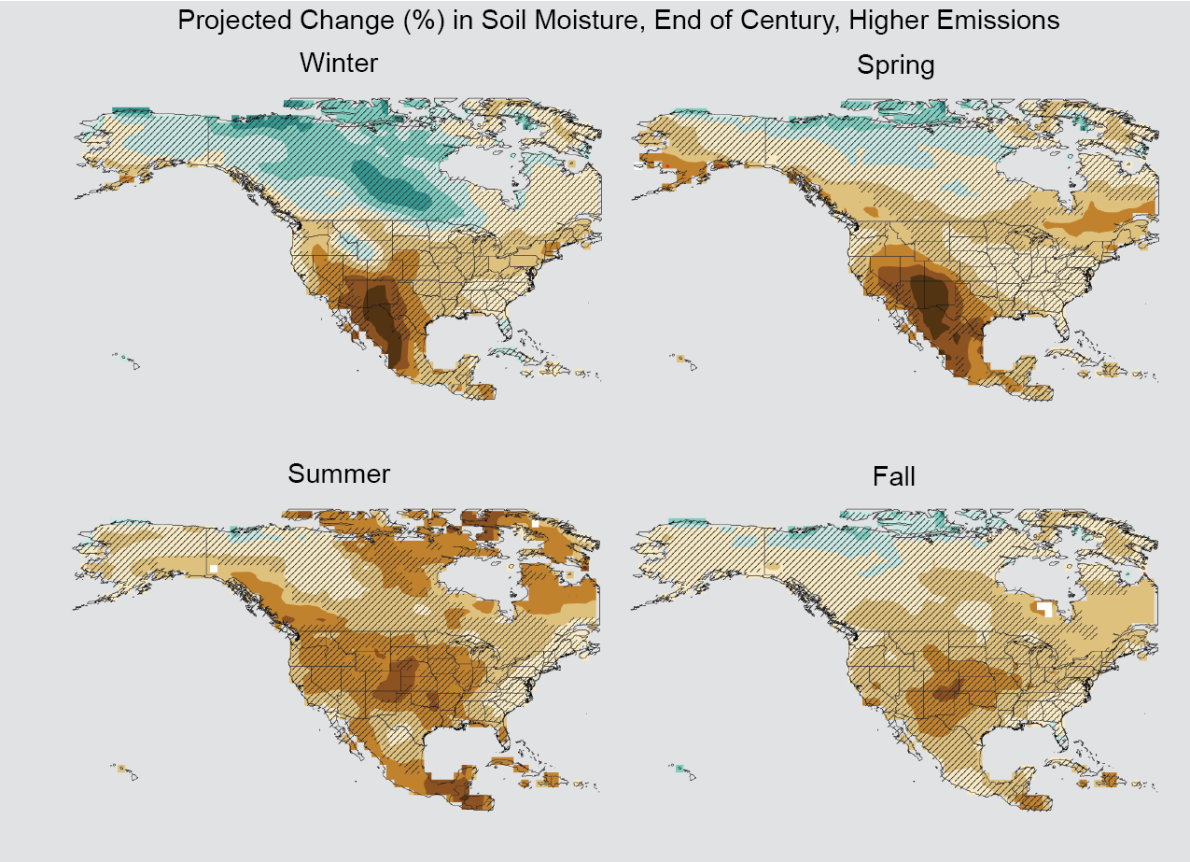
… but much evidence is found for a human influence on surface soil moisture deficits due to increased evapotranspiration caused by higher temperatures. (*High confidence*)

- Observations are very limited. Pointwise and sparse.
  - But land surface model reconstructions can reproduce them.
- Evapotranspiration increases with temperature.
  - Outpaces any (natural) precipitation increases, if any.

- A number of individual drought attribution studies show some evidence of a human influence

Soil moisture

- KM #3: Future decreases in surface (top 10 cm) soil moisture from anthropogenic forcing over most of the United States are *likely* as the climate warms under higher scenarios. (Medium confidence)



- Evapotranspiration increases with temperature.
  - Outpaces projected future precipitation increases, if any.

Agricultural drought attribution studies

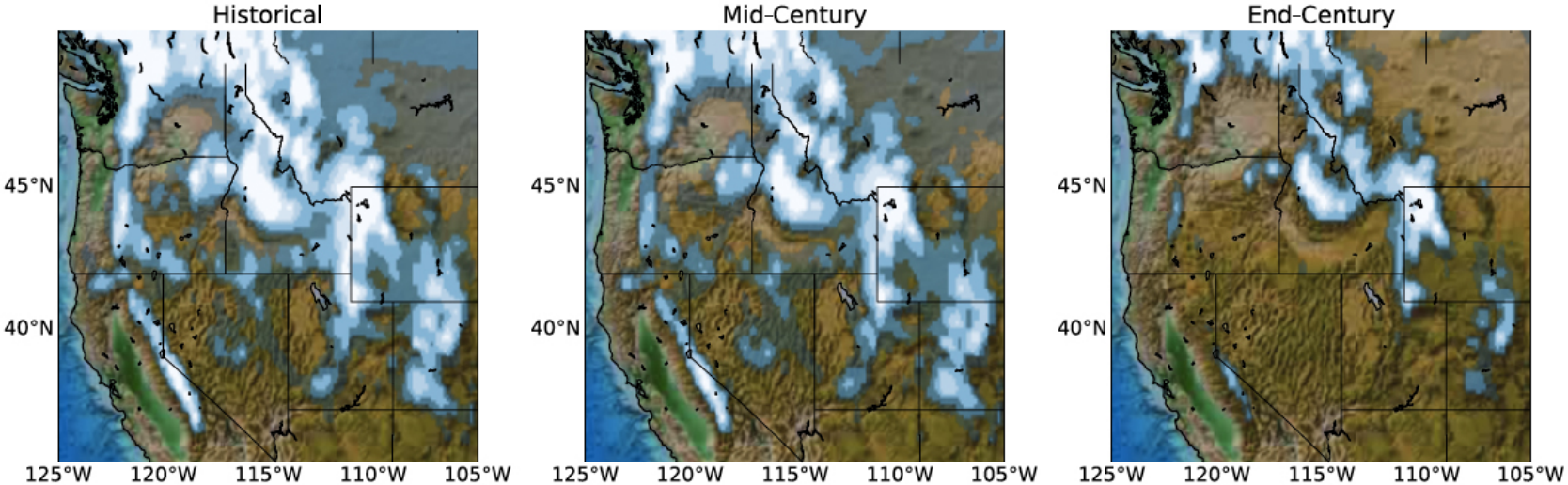
Authors	Event Year and Duration	Region or State	Type	Attribution Statement
Diffenbaugh et al. 2015	2012-2014	California	Agricultural	+
Seager et al. 2015	2012-2014	California	Agricultural	+
Cheng et al. 2016	2011-2015	California	Agricultural	-

- Confidence is generally higher for attribution of agricultural drought because of the sensitivity of evapotranspiration to temperature.
  - Attribution of anomalous high temperatures is generally straightforward.
- Land surface feedbacks are important.
  - As the ground dries out, evaporative cooling decreases, leading to yet higher local temperatures.
  - But soil moisture at depth may respond differently than at the surface.
  - Large uncertainty remains.

Key message #4

Substantial reductions in western U.S. winter and spring snowpack are projected as the climate warms. Earlier spring melt and reduced snow water equivalent have been formally attributed to human induced warming (*high confidence*) and will *very likely* be exacerbated as the climate continues to warm (*very high confidence*). Under higher emissions scenarios, and assuming no change to current water resources management, chronic, long-duration hydrological drought is increasingly possible by the end of this century (*very high confidence*).

Future Western US Snowpack under RCP8.5



Mountain Range	Snow Water Equivalent (% Change)		Snow Cover (% Change)		Snowfall (% Change)		Surface Temperature (Change in K)	
	2050	2100	2050	2100	2050	2100	2050	2100
Cascades	-41.5	-89.9	-21.6	-72.9	-10.7	-50.0	0.9	4.1
Klamath	-50.7	-95.8	-38.6	-89.0	-23.1	-78.7	0.8	3.5
Rockies	-17.3	-65.1	-8.2	-43.1	1.7	-8.2	1.4	5.5
Sierra Nevada	-21.8	-89.0	-21.9	-77.7	-4.7	-66.6	1.1	4.5
Wasatch and Uinta	-18.9	-78.7	-14.2	-61.4	4.1	-34.6	1.8	6.1
Western USA	-22.3	-70.1	-12.7	-51.5	-1.6	-21.4	1.3	5.2

Key Message #5

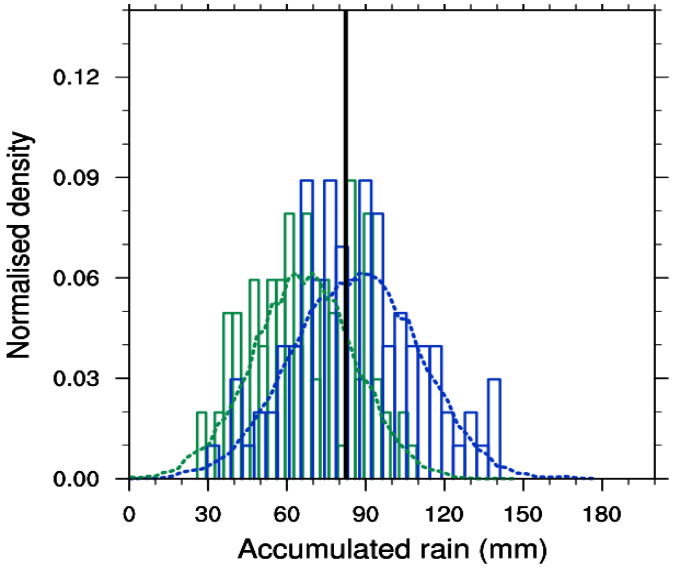
Detectable changes in some classes of flood frequency have occurred in parts of the United States and are a mix of increases and decreases. Extreme precipitation, one of the controlling factors in flood statistics, is observed to have generally increased and is projected to continue to do so across the United States in a warming atmosphere. However, formal attribution approaches have not established a significant connection of increased riverine flooding to human-induced climate change, and the timing of any emergence of a future detectable anthropogenic change in flooding is unclear. (*Medium confidence*)

Floods

- Observed trends in floods are complex.
  - Recall that observed US seasonal average precipitation trends are largely natural.
    - Hence, any observed trends in seasonal flooding of large rivers then is likely also natural.
    - But late season rain on snow events complicates this analysis.
  - Global trends in **extreme** precipitation have been formally attributed to human changes to the climate system.
    - Attribution analyses of individual extreme US precipitation events have found a significant human influence.
    - Why not on the resulting floods?
      - Community and human resource limitations.

Flood attribution studies

- Two studies of the September 2013 Colorado floods:
  - Hoerling et al. find no influence
  - Pall et al. find a large influence
  - They may or may not be inconsistent as they consider the issue differently.
  - Attribution of storms is difficult.

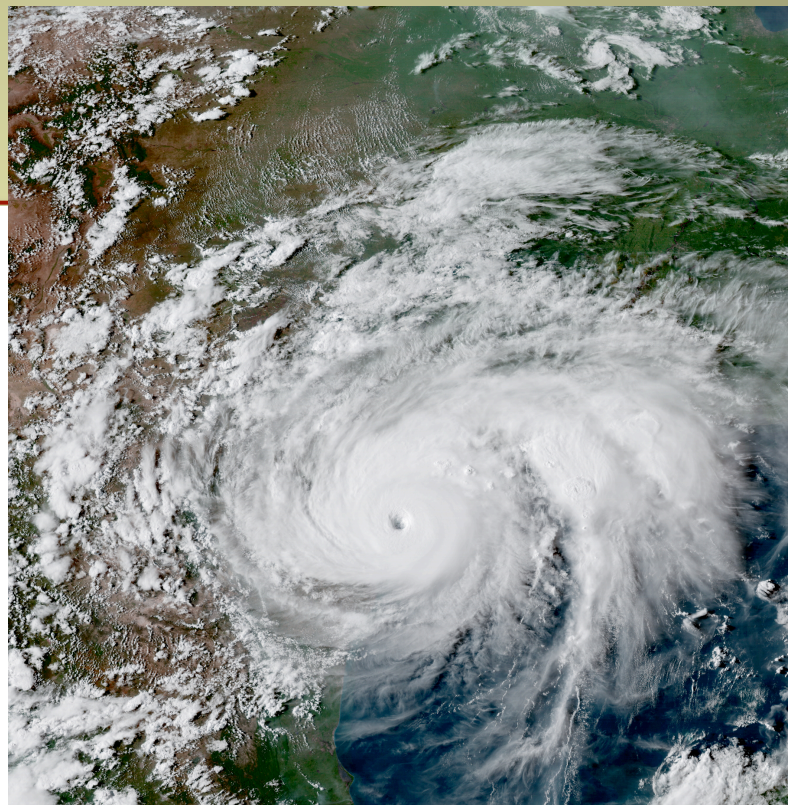


Pall et al. attribute a 30% increase in precipitation to human activity.

FEMA

Hurricane Harvey

NOAA GOES 16



- Harvey is not included in Volume 1,
  - but briefly is in Volume 2.
- Harvey was an unusual storm.
  - Stalled off the coast of Texas
  - Up to 60 inches of storm total rain

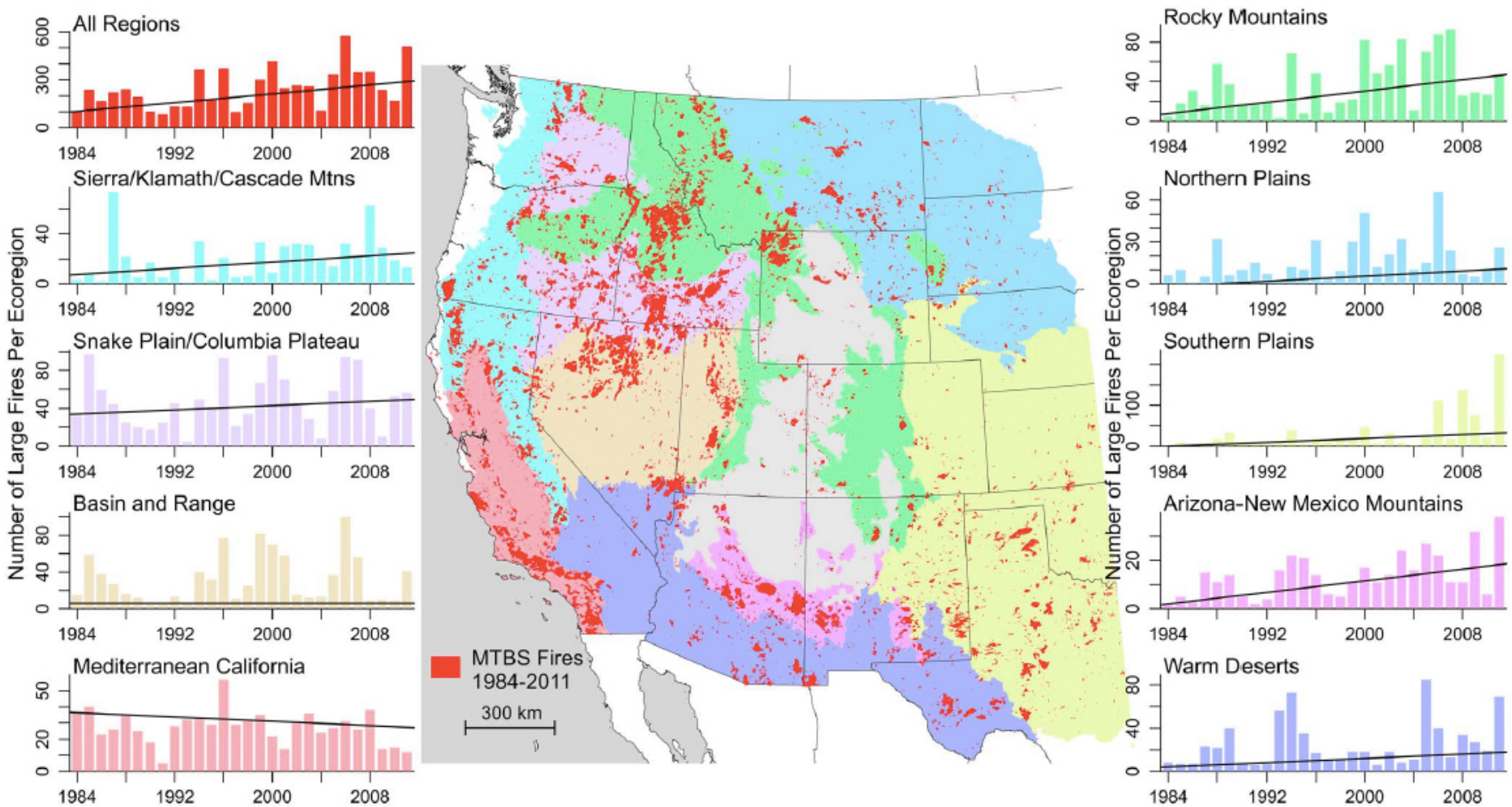
- 4 independent studies find a **large** human induced increase in Texas precipitation from Hurricane Harvey
  - All four studies within each others' uncertainty bounds!
  - Risser and Wehner (2017): *likely* at least a 19% increase; best estimate of 38%
  - Van Oldenborg et al. (2017): *very likely a* 15% increase; range of 8-19%
  - Wang et al. (2018): best estimate of a 20% increase (interquartile range of 13-37%)

Key message #6

The incidence of large forest fires in the western United States and Alaska has increased since the early 1980s (*high confidence*) and is projected to further increase in those regions as the climate warms, with profound changes to certain ecosystems (*medium confidence*).

FEMA

Figure 8.4. Observed increases in “large” fires



Western US wildfires and climate change

- Two human factors have increased the risk of fire.
  - Forest management changes increases fuel availability.
  - Warmer temperatures leads to greater evapotranspiration.
    - More flammable.
    - Longer fire season. Forest become flammable earlier.
  - Both of these are important.
- Both attribution and projection studies are extremely limited.
  - Future increases in summer temperatures will certainly extend the fire season, perhaps in some places to be nearly the entire year.
  - Decreased water availability, insect infestations may reduce fuel availability in the future.

https://science2017.globalchange.gov/

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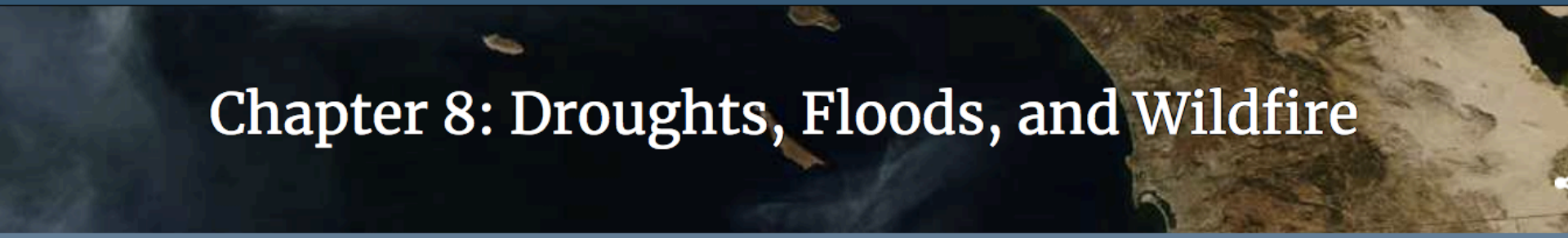

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Key Findings

Key Finding 1

Recent droughts and associated heat waves have reached record intensity in some regions of the United States; however, by geographical scale and duration, the Dust Bowl era of the 1930s remains the benchmark drought and extreme heat event in the historical record (*very high confidence*). While by some measures drought has decreased over much of the continental United States in association with long-term increases in precipitation, neither the precipitation increases nor inferred drought decreases have been confidently attributed to anthropogenic forcing.

Supporting Evidence

Questions?

Thank you!

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