North Central Texas Council of Governments

What Water Planners in Texas Need to Know About Climate (And I Wish I Could Tell You)

NCTCOG Webinar
February 23, 2022

Prepared in cooperation with the Texas Commission on Environmental Quality and U.S. Environmental Protection Agency

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North Central Texas Council of Governments
Environment & Development

www.nctcog.org/WaterResources

Procedures for Webinar

- The webinar will be recorded and posted to NCTCOG's website under the green banner called "Webinars" here: https://www.nctcog.org/envir/natural-resources/water-resources

- If you submitted an RSVP for this webinar, you will receive an email with the presentation, and eventually, a link to the recording. If you did not RSVP and would like these webinar materials, please email eberg@nctcog.org or type your email address in the chat.

- Please keep your microphone on mute until the Question-and-Answer period at the end of the presentation.

- Thank you!

Speaker Introduction

Dr. John Nielsen-Gammon

- Regents Professor of Atmospheric Sciences, Texas A&M University
- Texas State Climatologist
- Director of the Southern Regional Climate Center

What Water Planners in Texas Need to Know about Climate (and I wish I could tell you)

John W. Nielsen-Gammon

Texas A&M University

Earth's Future

RESEARCH ARTICLE
10.1029/2020EF001552

Key Points:
- Water stakeholders should prepare for future droughts that will be unlike past droughts
- Information available from climate projections often does not align with the detailed information needed for water planning
- Better awareness of the mismatch between available and needed information will help inform efforts to close this gap

Supporting Information:
- Supporting Information S1

Correspondence to:
J. W. Nielsen-Gammon,
n-g@tamu.edu

Citation:
Nielsen-Gammon, J. W., Banner, J. L., Cook, B. I., Tremaine, D. M., Wong, C. I., Mace, R. E., et al. (2020).

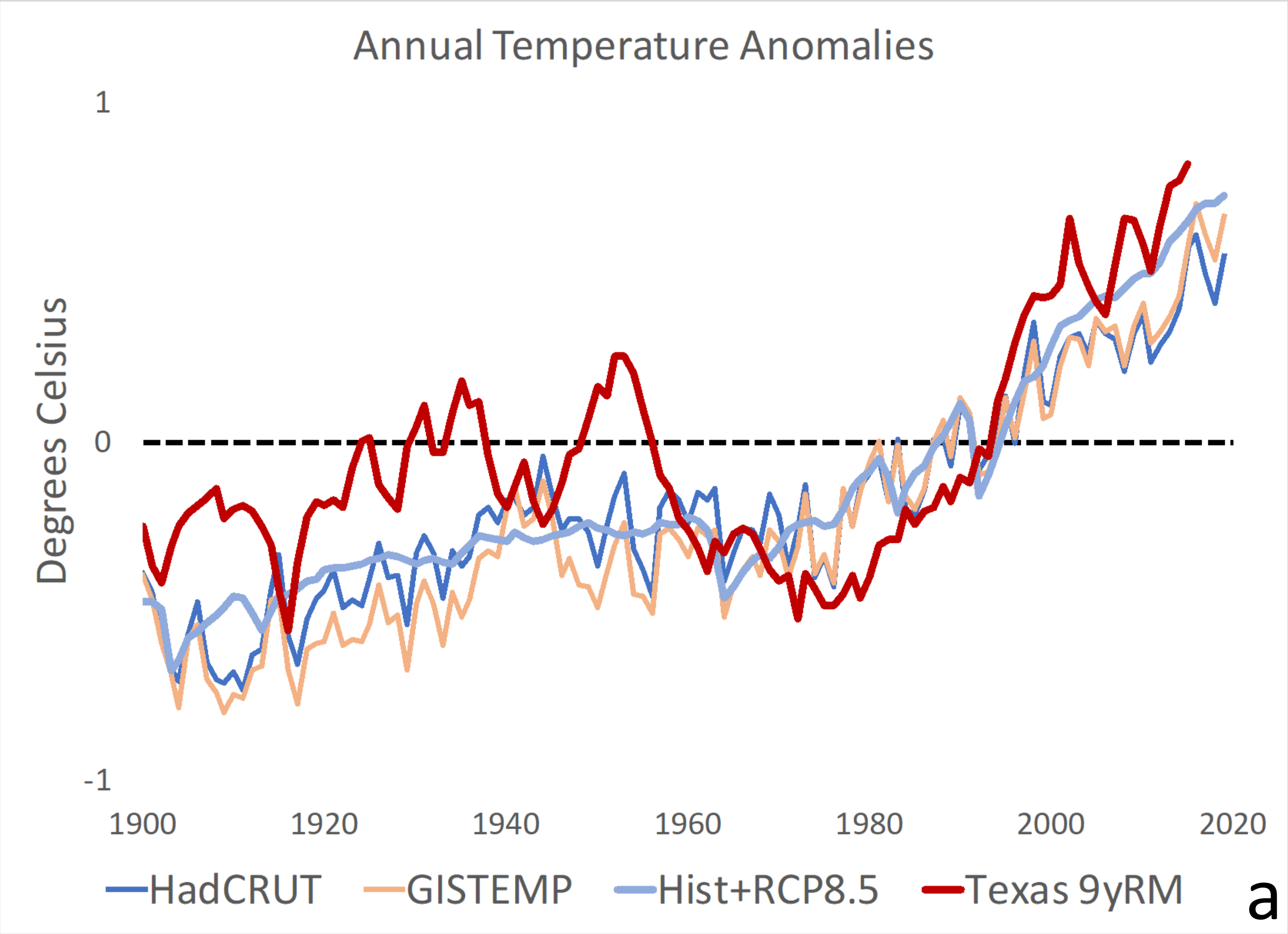
Unprecedented Drought Challenges for Texas Water Resources in a Changing Climate: What Do Researchers and Stakeholders Need to Know?

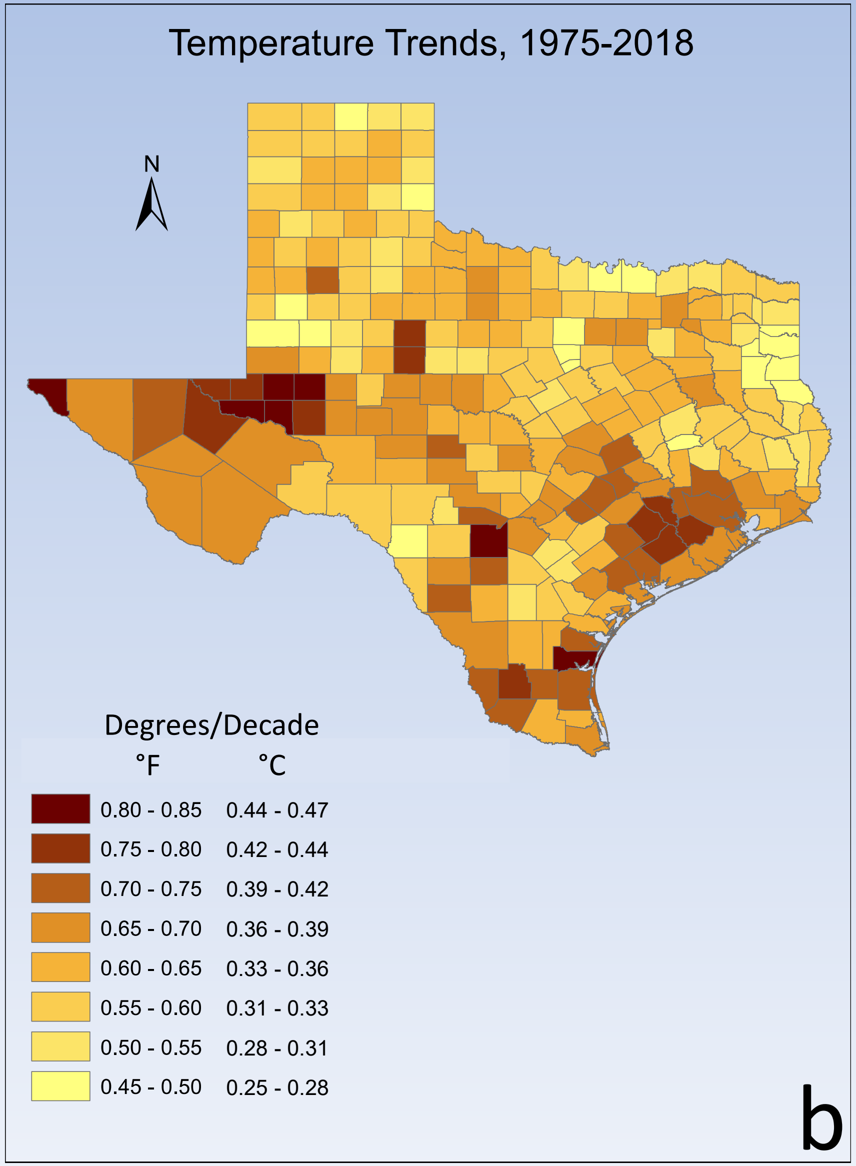
John W. Nielsen-Gammon[1], Jay L. Banner[2,3], Benjamin I. Cook[4,5], Darrel M. Tremaine[2,3], Corinne I. Wong[3,12], Robert E. Mace[6], Huilin Gao[7], Zong-Liang Yang[2], Marisa Flores Gonzalez[8], Richard Hoffpauir[9], Tom Gooch[10], and Kevin Kloesel[11]

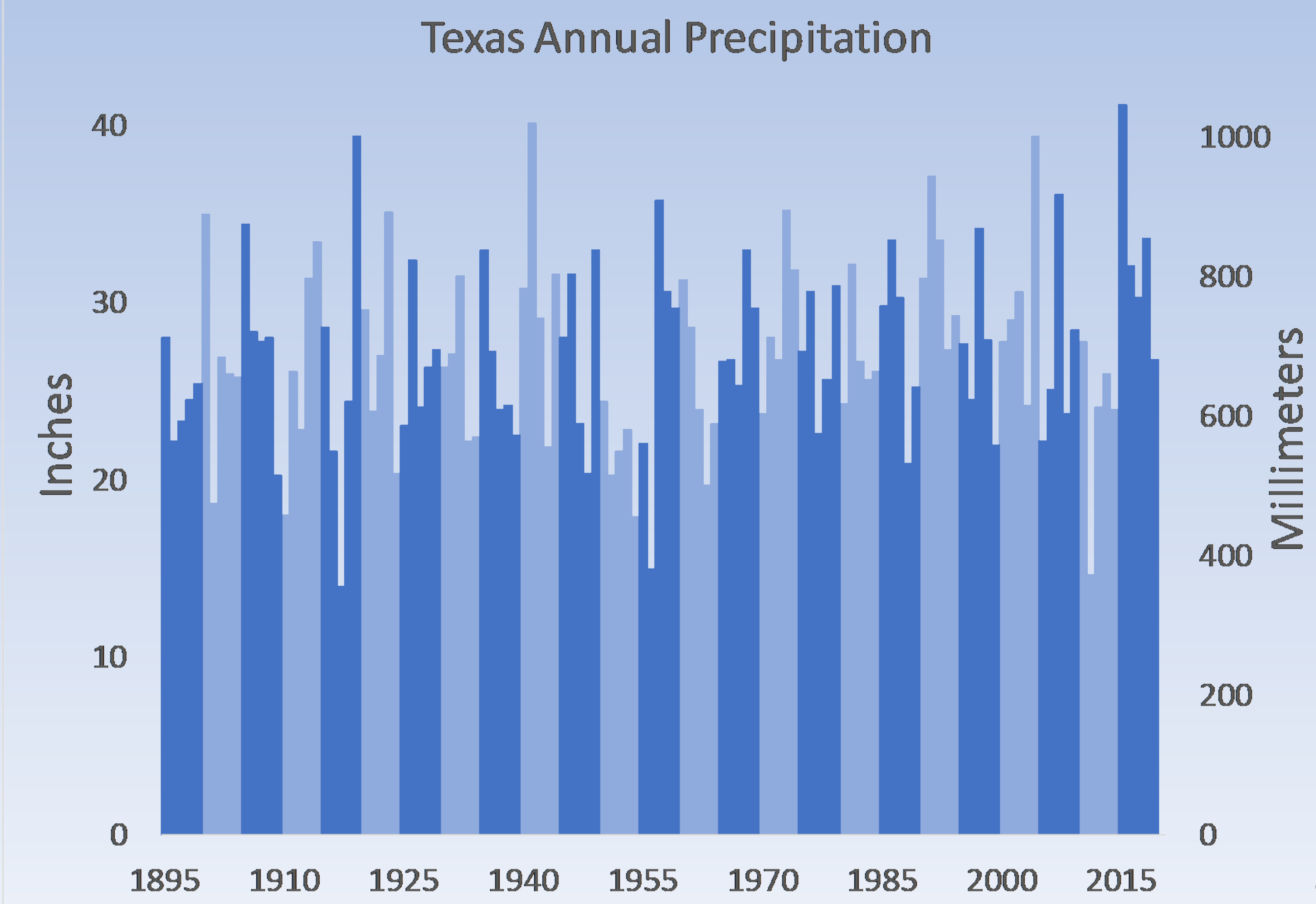
[1]Department of Atmospheric Sciences, Texas A&M University, College Station, TX, USA, [2]Department of Geological Sciences, University of Texas at Austin, Austin, TX, USA, [3]Environmental Science Institute, University of Texas at Austin, Austin, TX, USA, [4]NASA Goddard Institute for Space Studies, New York, NY, USA, [5]Division of Ocean and Climate Physics, Lamont-Doherty Earth Observatory, Palisades, NY, USA, [6]The Meadows Center for Water and the Environment, Texas State University, San Marcos, TX, USA, [7]Department of Civil and Environmental Engineering, Texas A&M University, College Station, TX, USA, [8]Water Forward, City of Austin, Austin, TX, USA, [9]Hoffpauir Consulting, PLLC, Bryan, TX, USA, [10]Freese and Nichols Inc., Fort Worth, TX, USA, [11]College of Atmospheric and Geographic Sciences, University of Oklahoma, Norman, OK, USA, [12]Now at Facebook, Inc., Austin, TX, USA

Abstract Long-range water planning is complicated by factors that are rapidly changing in the 21st century, including climate, population, and water use. Here, we analyze climate factors and drought projections for Texas as an example of a diverse society straddling an aridity gradient to examine how the projections can best serve water stakeholder needs. We find that climate models are robust in projecting drying of summer-season soil moisture and decreasing reservoir supplies for both the eastern and western

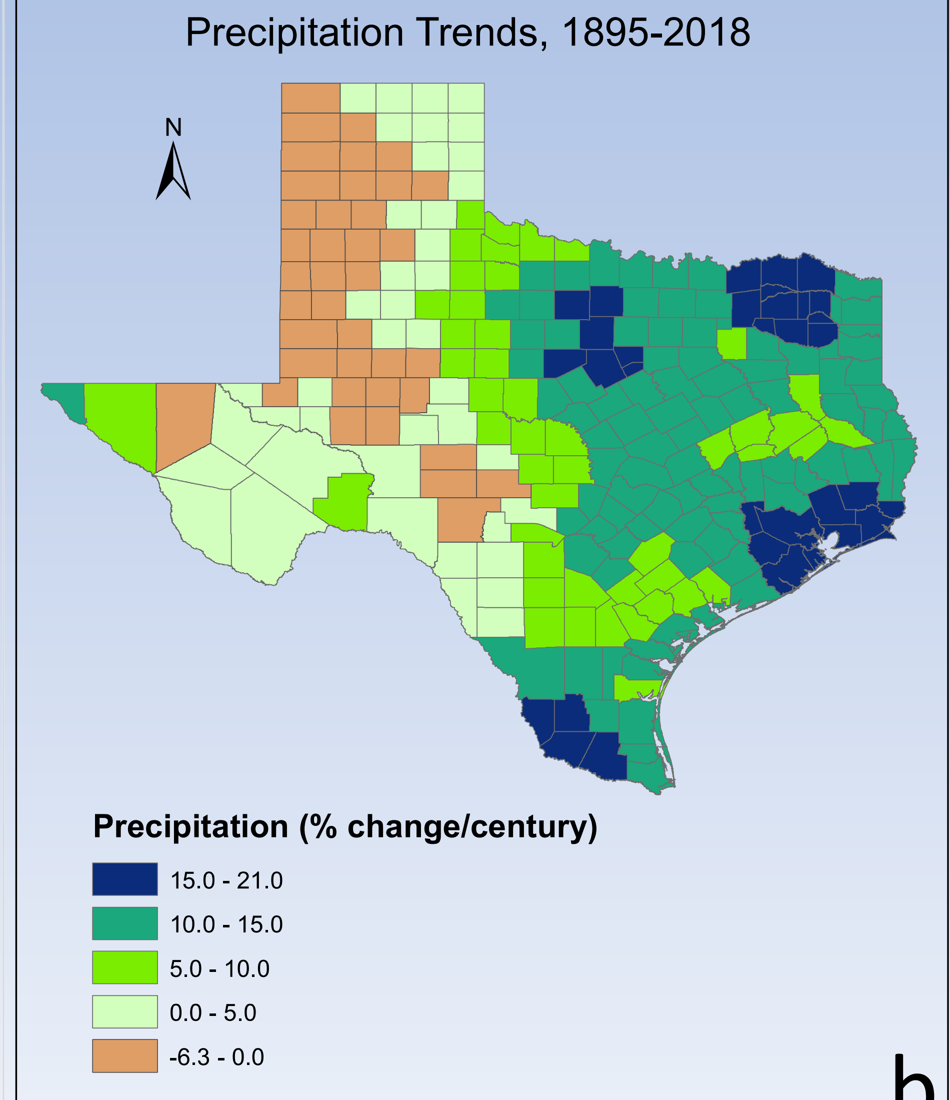
Supported by: The National Science Foundation Coupled Natural and Human Systems program, grant number AGS-1518541, the Cynthia and George Mitchell Foundation grant number G-1809-55892, and by The University of Texas at Austin's Planet Texas 2050 Bridging Barriers research initiative.


Annual Temperature Anomalies
1
0
-1
Degrees Celsius
1900
1920
1940
1960
1980
2000
2020
HadCRUT
GISTEMP
Hist+RCP8.5
Texas 9yRM
a


Temperature Trends, 1975-2018
N
Degrees/Decade
°F °C
0.80 - 0.85 0.44 - 0.47
0.75 - 0.80 0.42 - 0.44
0.70 - 0.75 0.39 - 0.42
0.65 - 0.70 0.36 - 0.39
0.60 - 0.65 0.33 - 0.36
0.55 - 0.60 0.31 - 0.33
0.50 - 0.55 0.28 - 0.31
0.45 - 0.50 0.25 - 0.28
b


Texas Annual Precipitation
Inches
Millimeters
0
10
20
30
40
0
200
400
600
800
1000
1895
1910
1925
1940
1955
1970
1985
2000
2015

a


Precipitation Trends, 1895-2018
N
Precipitation (% change/century)
15.0 - 21.0
10.0 - 15.0
5.0 - 10.0
0.0 - 5.0
-6.3 - 0.0

b

RESEARCH ARTICLE

CLIMATOLOGY

Unprecedented 21st century drought risk in the American Southwest and Central Plains

10.1126/sciadv.1400082

Benjamin I. Cook,[1,2]* Toby R. Ault,[3] Jason E. Smerdon[2]

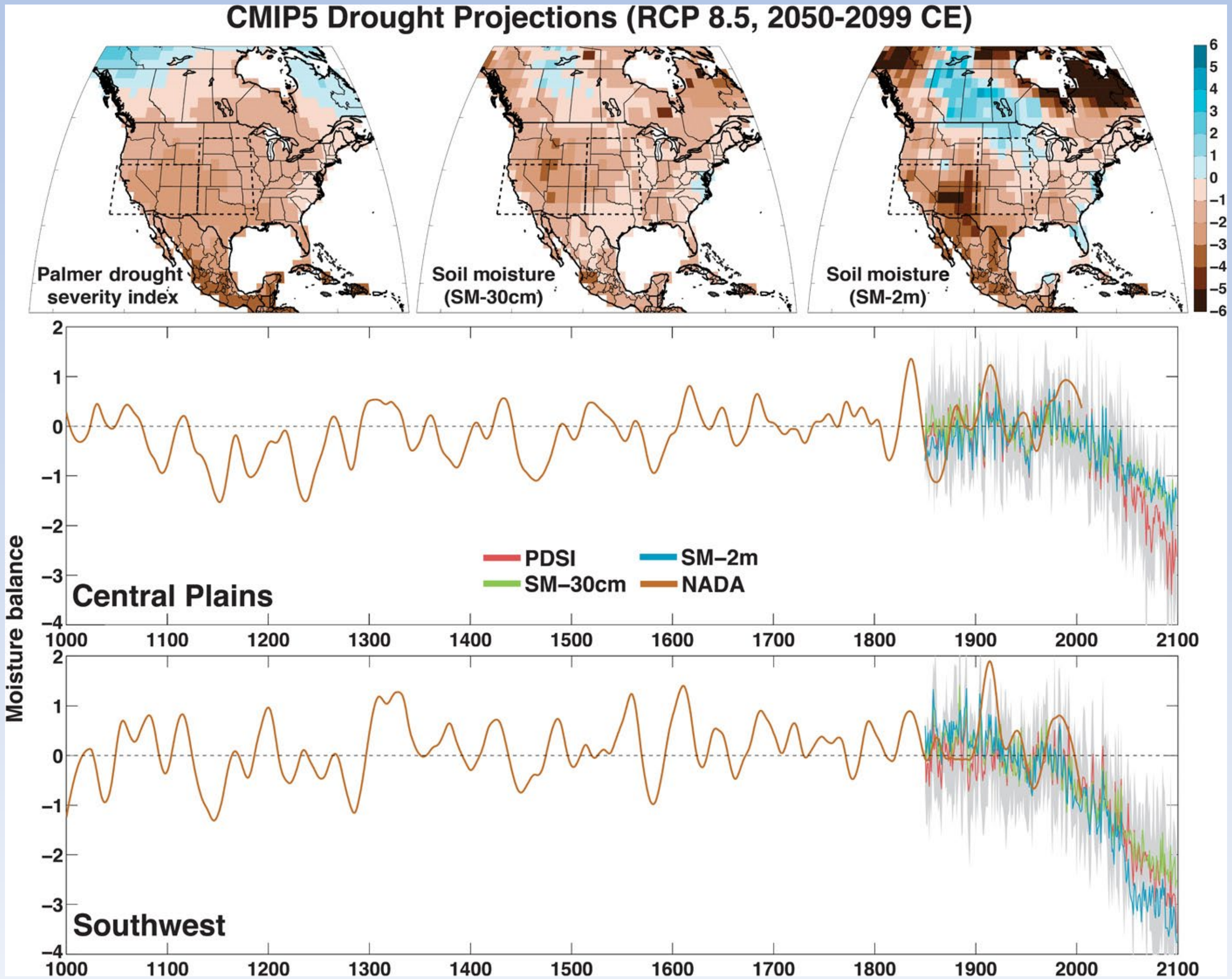
In the Southwest and Central Plains of Western North America, climate change is expected to increase drought severity in the coming decades. These regions nevertheless experienced extended Medieval-era droughts that were more persistent than any historical event, providing crucial targets in the paleoclimate record for benchmarking the severity of future drought risks. We use an empirical drought reconstruction and three soil moisture metrics from 17 state-of-the-art general circulation models to show that these models project significantly drier conditions in the later half of the 21st century compared to the 20th century and earlier paleoclimatic intervals. This desiccation is consistent across most of the models and moisture balance variables, indicating a coherent and robust drying response to warming despite the diversity of models and metrics analyzed. Notably, future drought risk will likely exceed even the driest centuries of the Medieval Climate Anomaly (1100–1300 CE) in both moderate (RCP 4.5) and high (RCP 8.5) future emissions scenarios, leading to unprecedented drought conditions during the last millennium.

INTRODUCTION

Millennial-length hydroclimate reconstructions over Western North America (*1*–*4*) feature notable periods of extensive and persistent

used to compare variability and trends in drought across regions. Average moisture conditions (relative to a defined baseline) are denoted by PDSI = 0; negative PDSI values indicate drier than average conditions

Fig. 1 Top: Multimodel mean summer (JJA) PDSI and standardized soil moisture (SM-30cm and SM-2m) over North America for 2050–2099 from 17 CMIP5 model projections using the RCP 8.5 emissions scenario.



Benjamin I. Cook et al. Sci Adv 2015;1:e1400082

RESEARCH

Science
Volume 368(6488):314-318
April 17, 2020

Science AAAS

DROUGHT

Large contribution from anthropogenic warming to an emerging North American megadrought

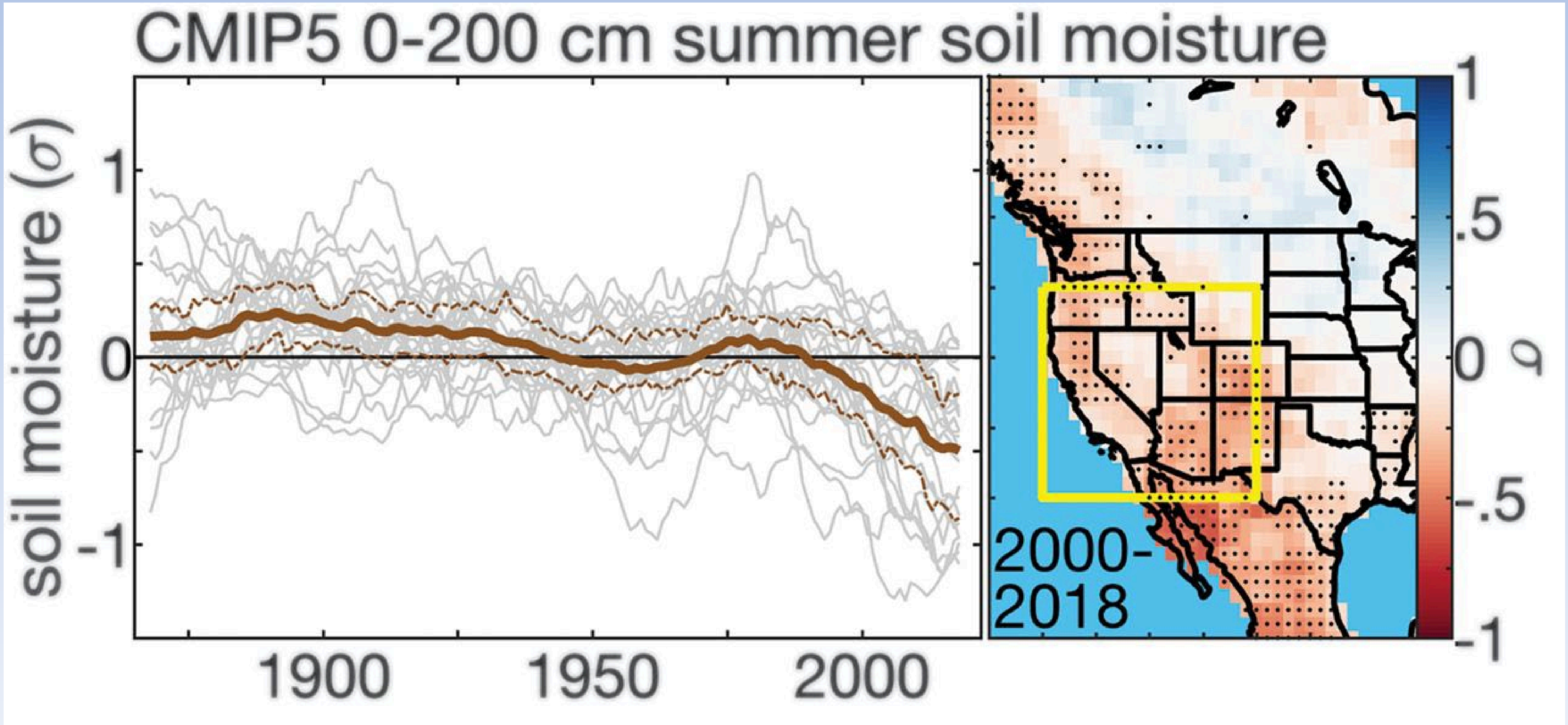
A. Park Williams[1]*, Edward R. Cook[1], Jason E. Smerdon[1], Benjamin I. Cook[1,2], John T. Abatzoglou[3,4], Kasey Bolles[1], Seung H. Baek[1,5], Andrew M. Badger[6,7,8], Ben Livneh[6,9]

Severe and persistent 21st-century drought in southwestern North America (SWNA) motivates comparisons to medieval megadroughts and questions about the role of anthropogenic climate change. We use hydrological modeling and new 1200-year tree-ring reconstructions of summer soil moisture to demonstrate that the 2000–2018 SWNA drought was the second driest 19-year period since 800 CE, exceeded only by a late-1500s megadrought. The megadrought-like trajectory of 2000–2018 soil moisture was driven by natural variability superimposed on drying due to anthropogenic warming. Anthropogenic trends in temperature, relative humidity, and precipitation estimated from 31 climate models account for 47% (model interquartiles of 35 to 105%) of the 2000–2018 drought severity, pushing an otherwise moderate drought onto a trajectory comparable to the worst SWNA megadroughts since 800 CE.

Southwestern North America (SWNA; western United States and northern Mexico:

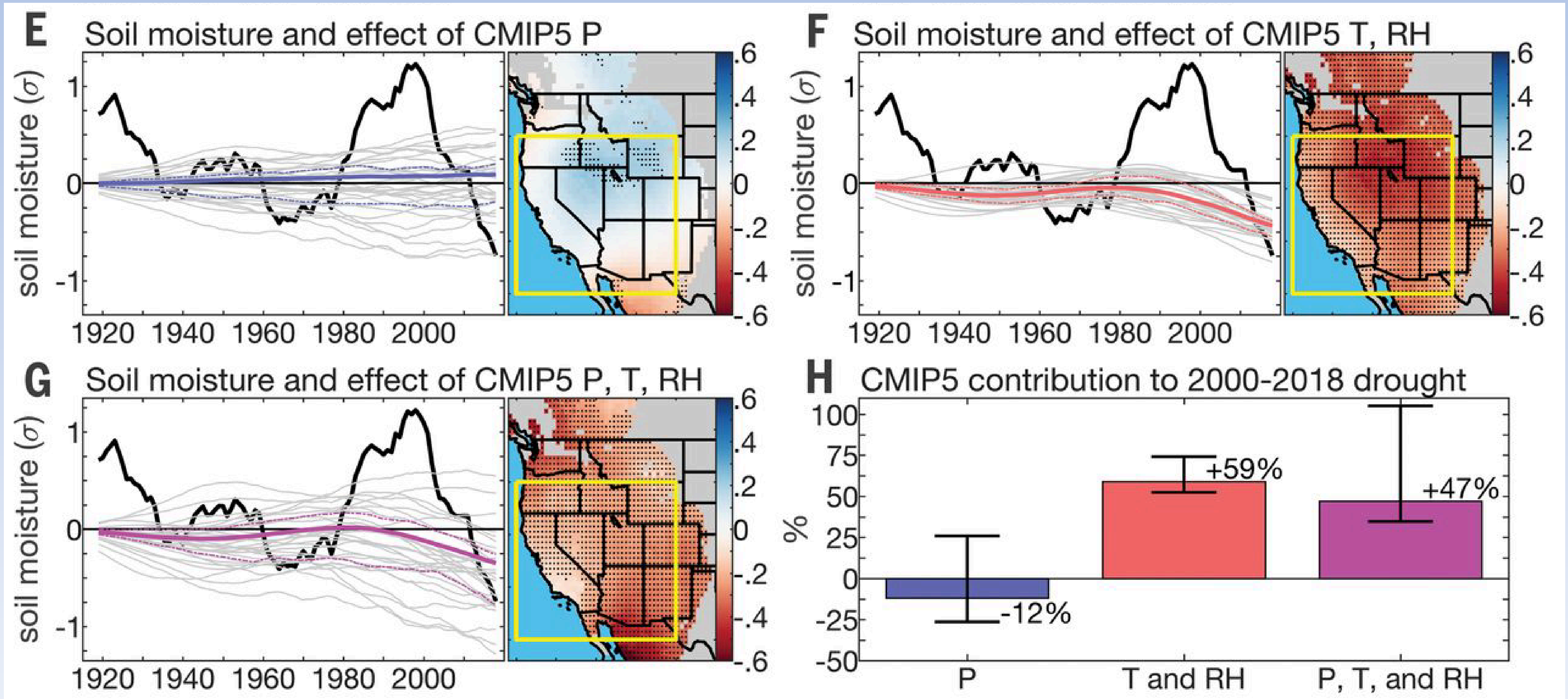
conditions have been clearly promoted by natural Pacific Ocean variability (*18–20*), certain

Fig. 4 Trends in summer soil moisture simulated directly from coupled models.



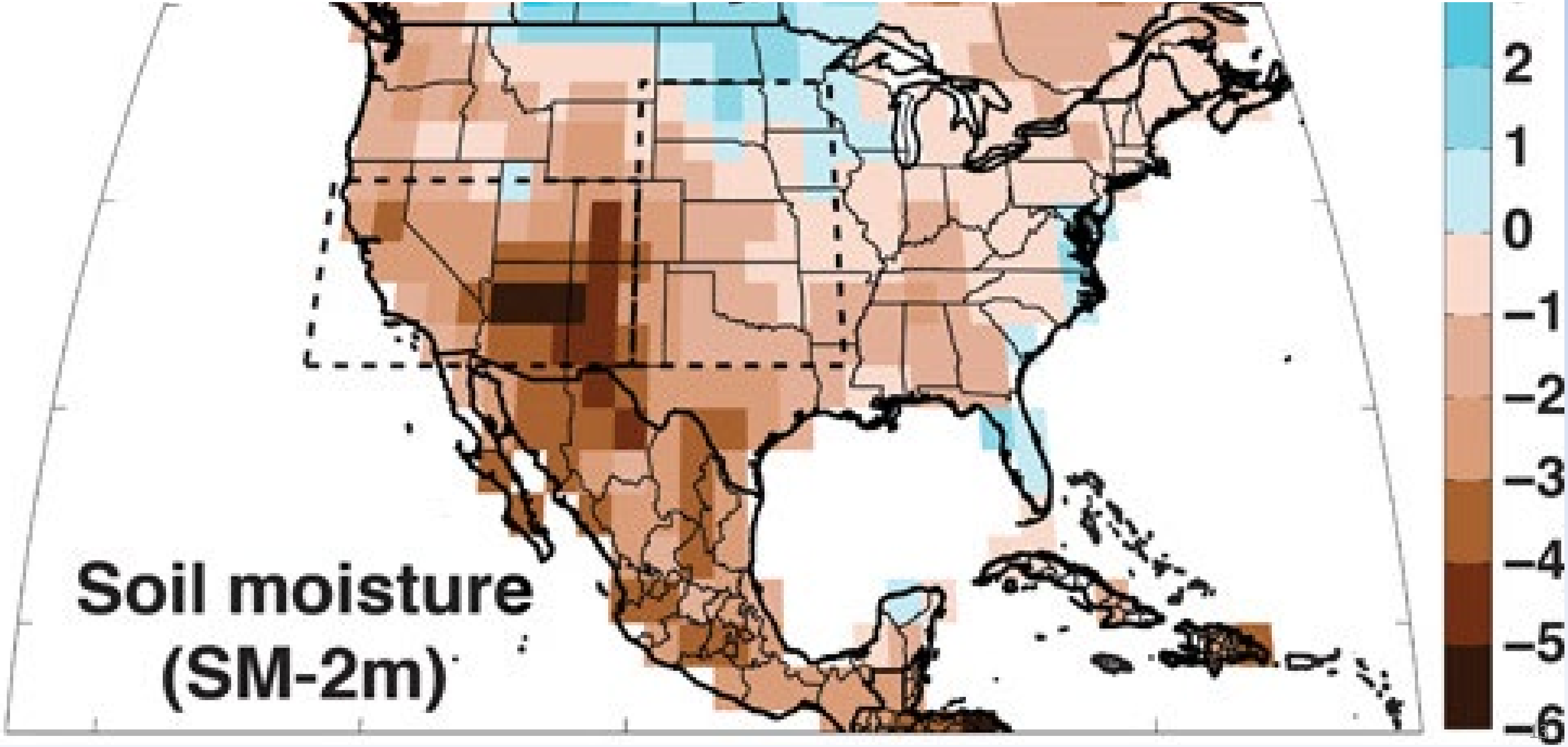
A. Park Williams et al. Science 2020;368:314-318

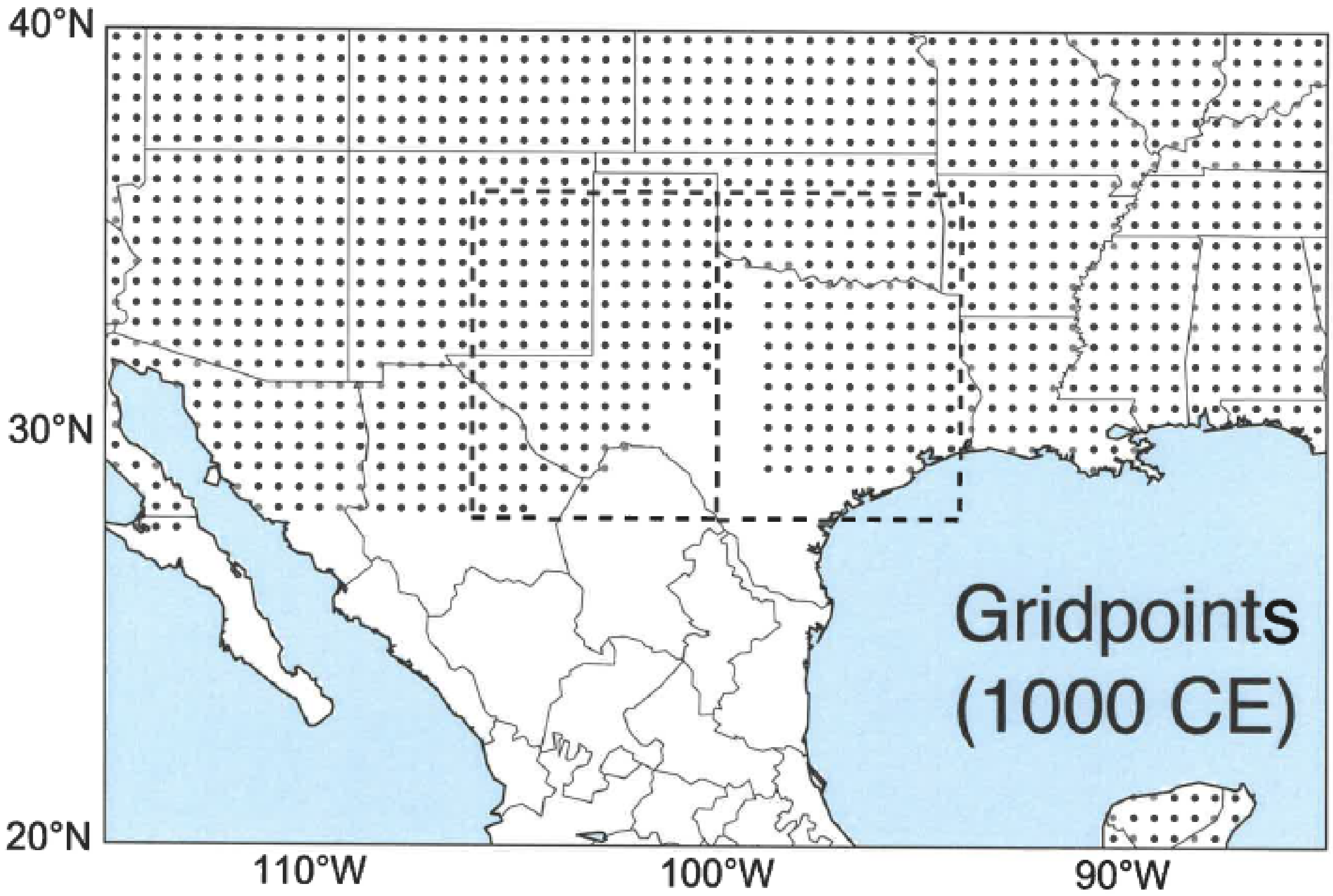
Fig. 2 Effects of anthropogenic climate trends.



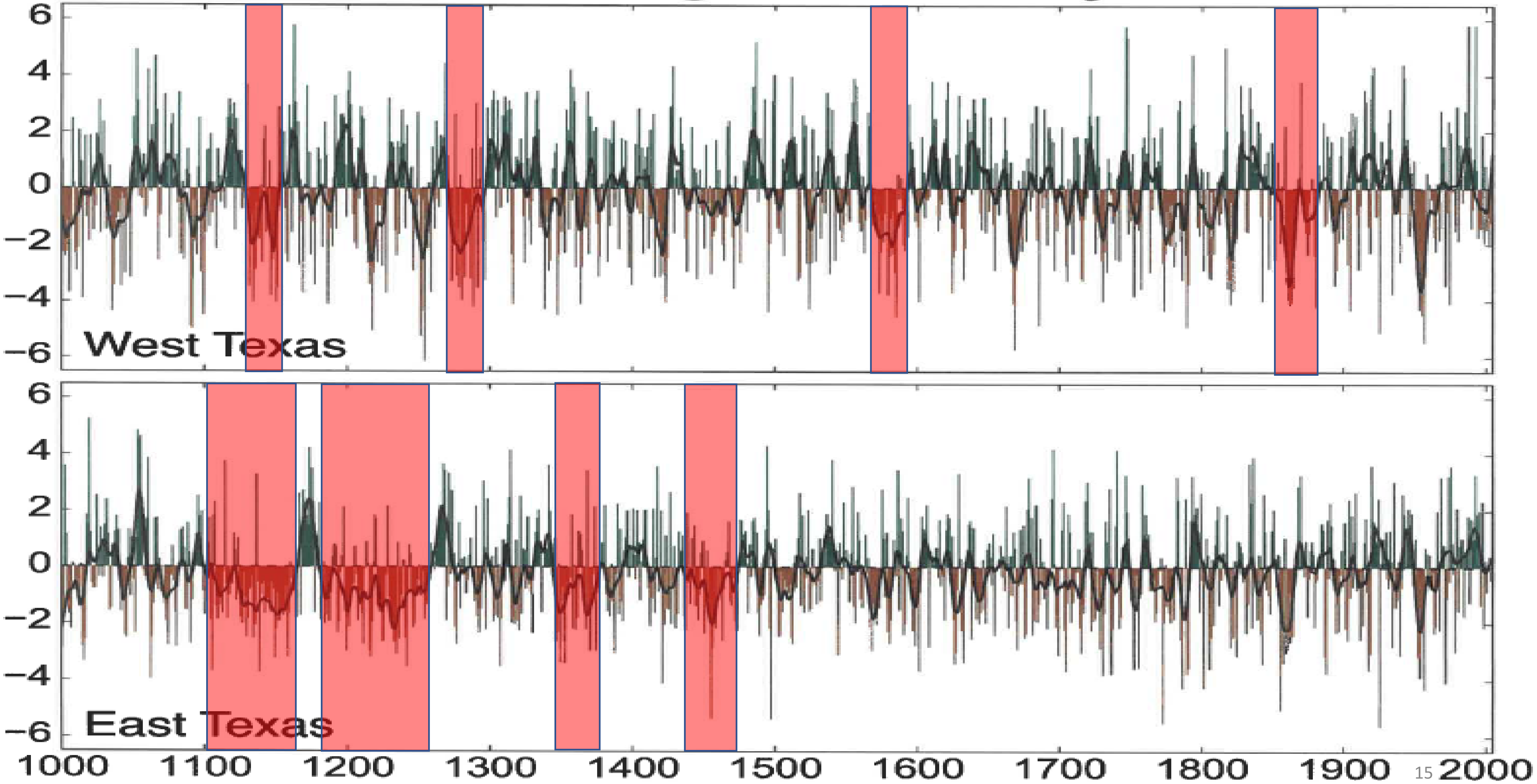
A. Park Williams et al. Science 2020;368:314-318

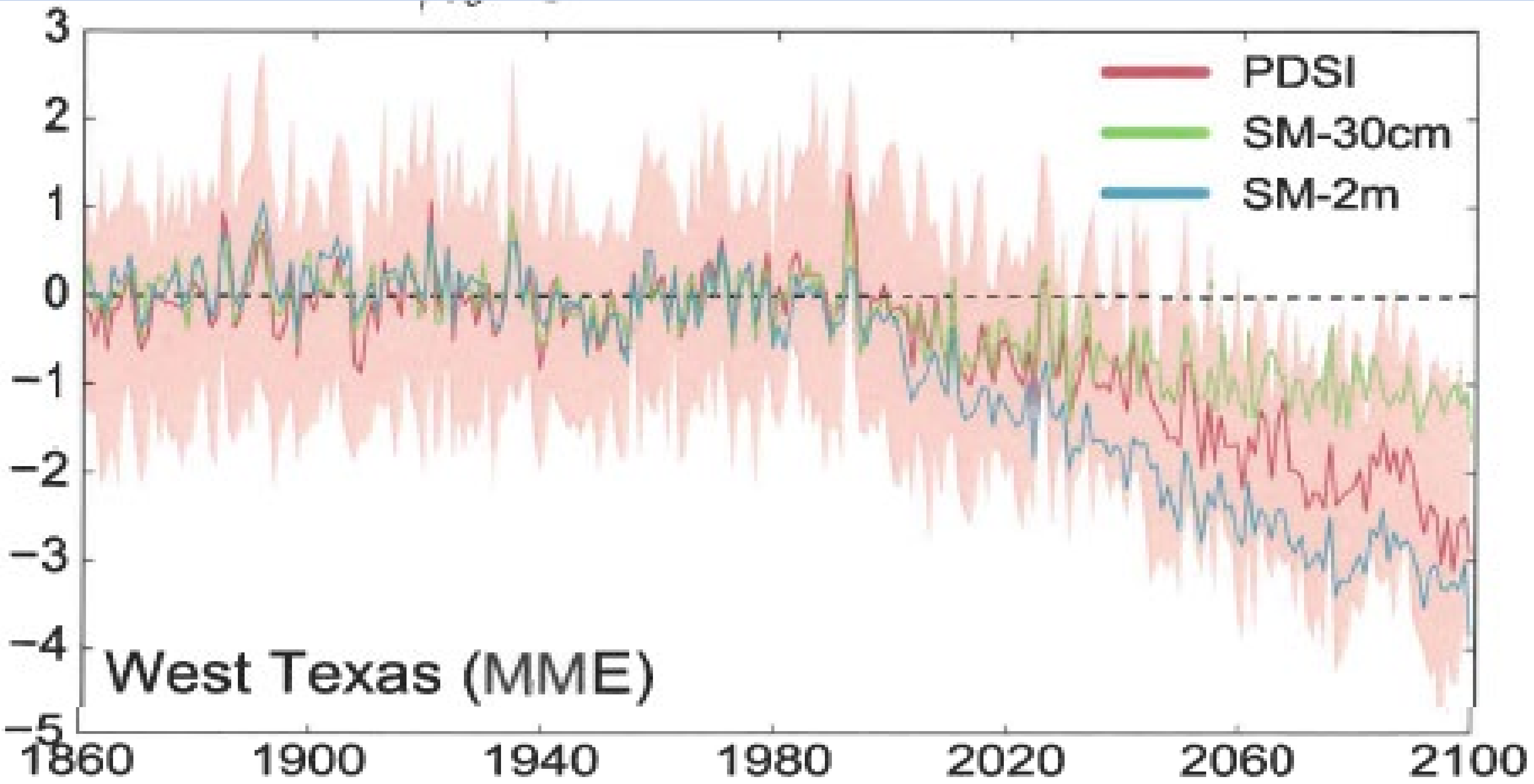
What about Texas?

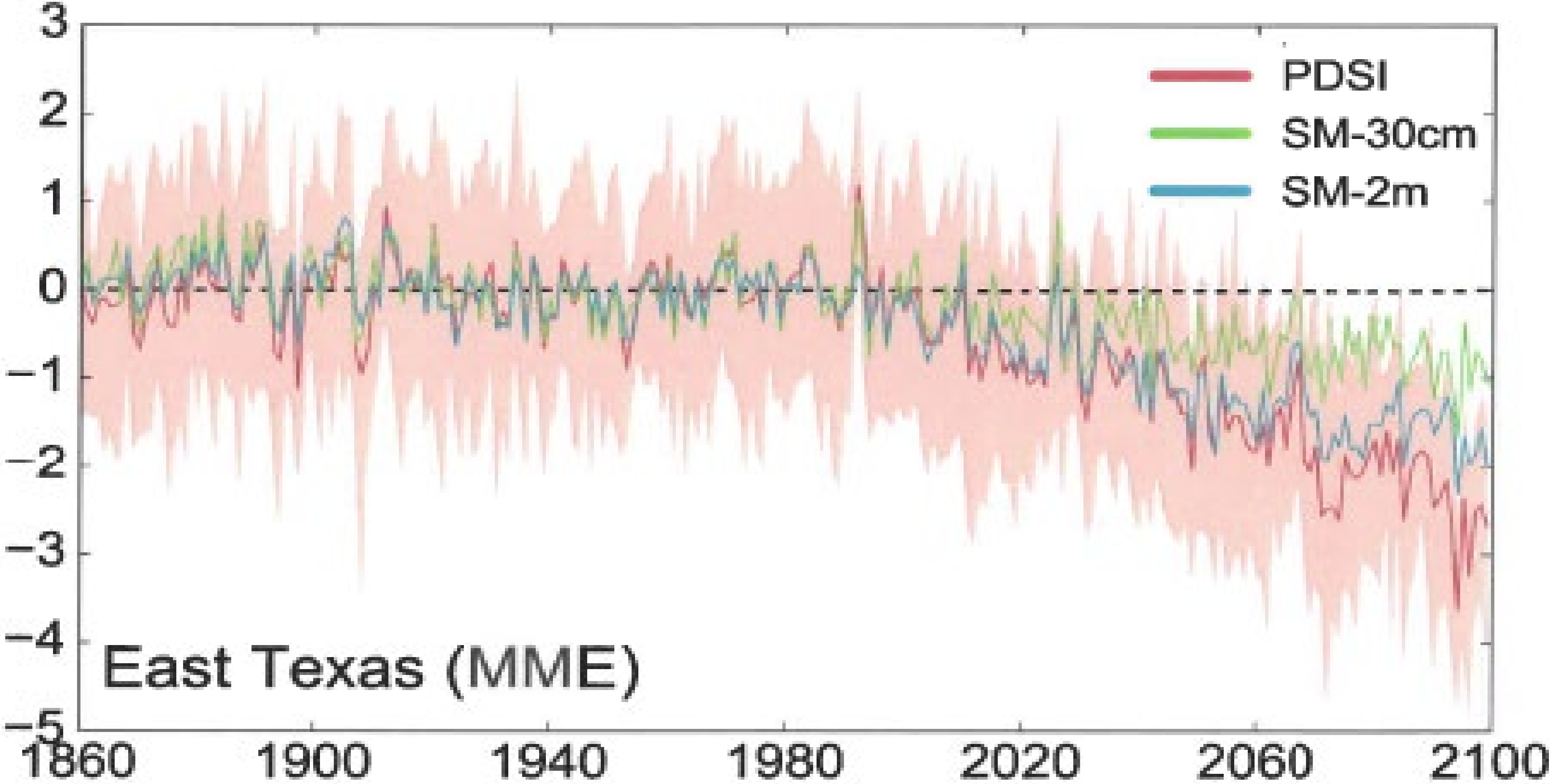



40°N
30°N
20°N
110°W
100°W
90°W
Gridpoints
(1000 CE)

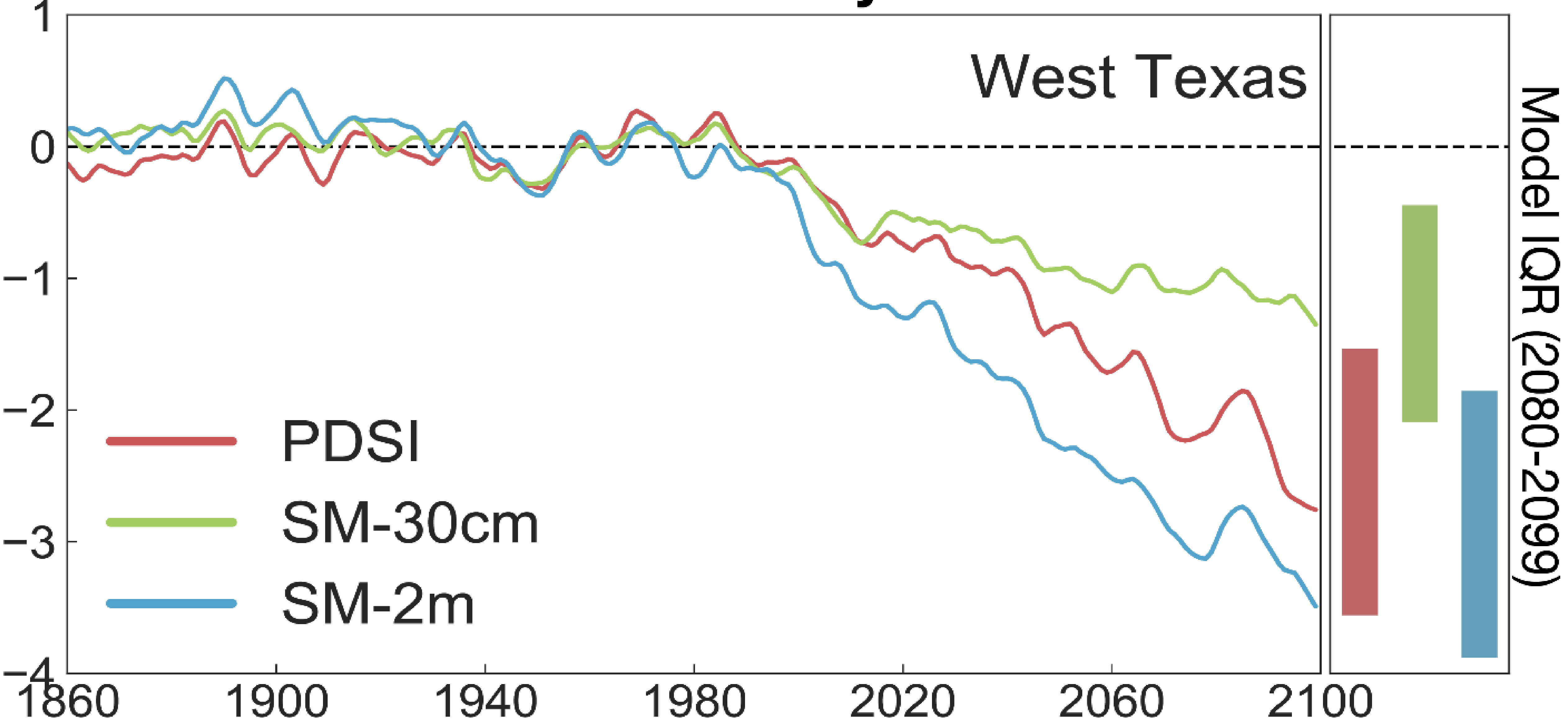
Palmer Drought Severity Index

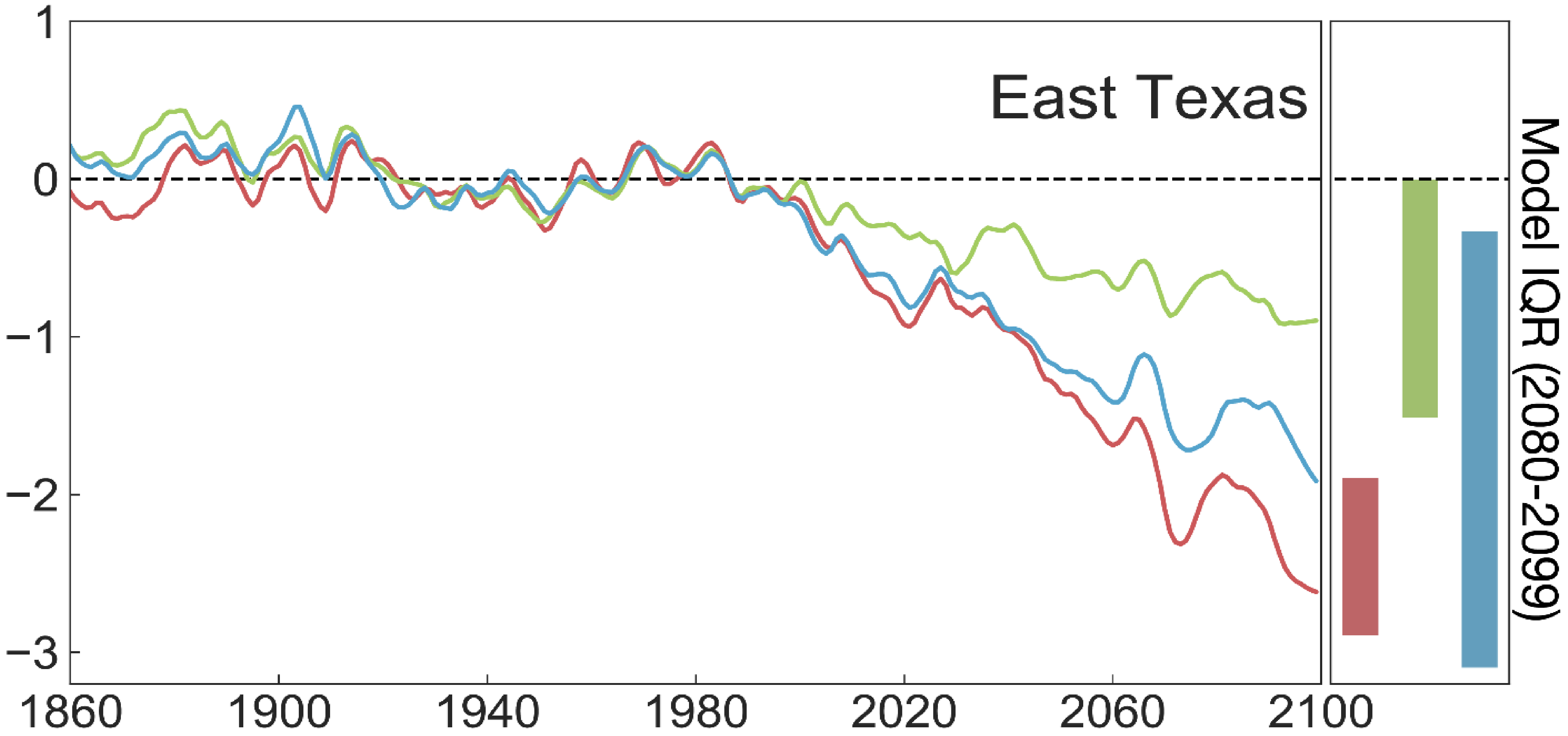


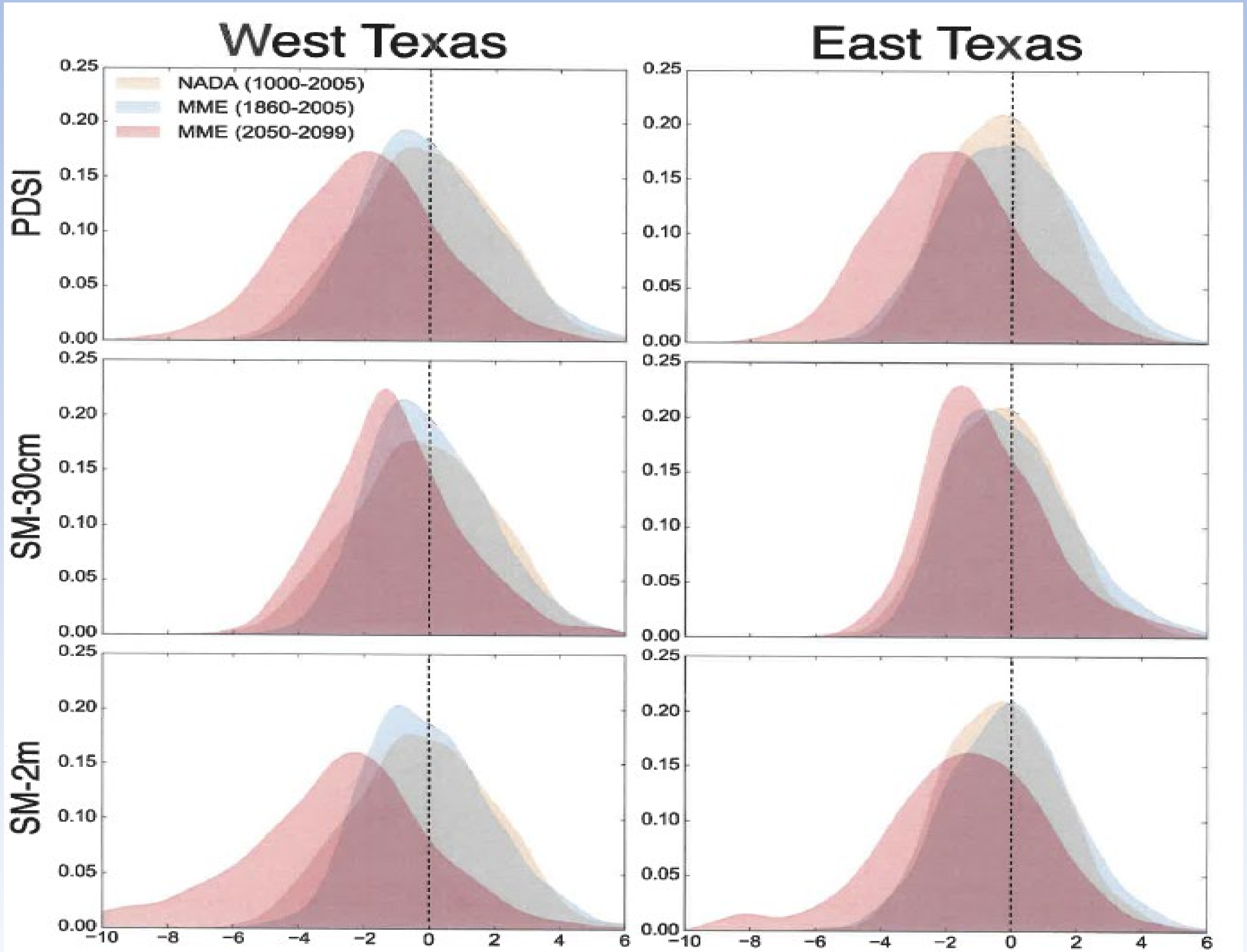

PDSI
SM-30cm
SM-2m
West Texas (MME)
3
2
1
0
−1
−2
−3
−4
−5
1860
1900
1940
1980
2020
2060
2100


PDSI
SM-30cm
SM-2m
East Texas (MME)
3
2
1
0
−1
−2
−3
−4
−5
1860
1900
1940
1980
2020
2060
2100

CMIP5 Projections




East Texas
1
0
−1
−2
−3
1860
1900
1940
1980
2020
2060
2100
Model IQR (2080-2099)


West Texas
East Texas
NADA (1000-2005)
MME (1860-2005)
MME (2050-2099)
PDSI
SM-30cm
SM-2m
0.25
0.20
0.15
0.10
0.05
0.00
−10
−8
−6
−4
−2
0
2
4
6

Attributing a trend to climate change

- Is there a clear historical trend?
- Do models project a consistent future trend?
- Is there a sound physical understanding of why there should be a trend?

Attributing a trend to climate change

- Is there a clear historical trend?
- Do models project a consistent future trend?
- Is there a sound physical understanding of why there should be a trend?
- Example: extreme cold
  - Clear historical trend: milder extreme cold
  - Consistent model projections: milder extreme cold
  - Physical understanding: warmer Arctic (but changing weather patterns)

Why more droughts? Or more aridity?

- **On the drying side…**
  - Changes in temperature
  - Changes in rainfall extremes, month to month
  - Changes in rainfall seasonality
- **On the wetting side…**
  - Changes in biosphere water use efficiency

On the unclear side…

- Changes in annual precipitation
- Changes in rainfall extremes, single storms
- Changes in biomass

What does this mean for surface water supply?

- Uncertainty for future
  - How much carbon dioxide etc.?
  - How much will the climate system respond?
  - How do we infer local details, given the climate system response?
  - How do we model the hydrology?
  - How important is all of this compared to natural variability?
- Also relevant: demand and flood resilience

What does this mean for groundwater supply?

- Fast-recharge aquifers: supply-driven impacts
- Slow-recharge aquifers: demand-driven impacts
- In between: demand-driven impacts + future supply-driven impacts

What do stakeholders really need to know? Case 1: Large surface water suppliers

- An estimate of resilience implied by planning for “drought of record”
- A way to incorporate future uncertainties and single-event planning
- Texas regulatory models that are set up to incorporate climate change

What do stakeholders really need to know? Case 2: Small groundwater management districts

- Prediction of demand-side response driven by climate change
- Technical expertise
- Short-term and long-term outlooks tailored to needs

What do stakeholders really need to know? Case 3: Regional water planning groups

- Understanding of climate-driven interactions
  - Rising temperatures: rising energy demand: increased cooling water needs
- Tools for designing climate-resilient water supply portfolios
- Ways of satisfying diverse stakeholders and diverse public opinions

What did Austin Water do?

- Water Forward: a 100-year integrated water resources plan
- Input: Global climate model projections of temperature and precipitation
- Input: Historical statistical relationship with streamflow
- Tool: Future scenarios = drought of record and 3x drought of record
- All info tailored for direct input to Water Availability Model
- Key: Working directly with climate scientists
- Now: Next iteration, including science advisory team

Earth's Future

RESEARCH ARTICLE
10.1029/2021EF002019

Special Section:
CMIP6: Trends, Interactions, and Impacts.

Key Points:

- Coupled Model Intercomparison Project models project changes to the annual cycle of many hydroclimate variables, many of which are more significant than annual mean changes
- In the continental United States, there are significant earlier shifts in the annual cycle in a high emissions scenario
- Significant changes to the annual cycle are largely avoided in the lowest-emissions scenario

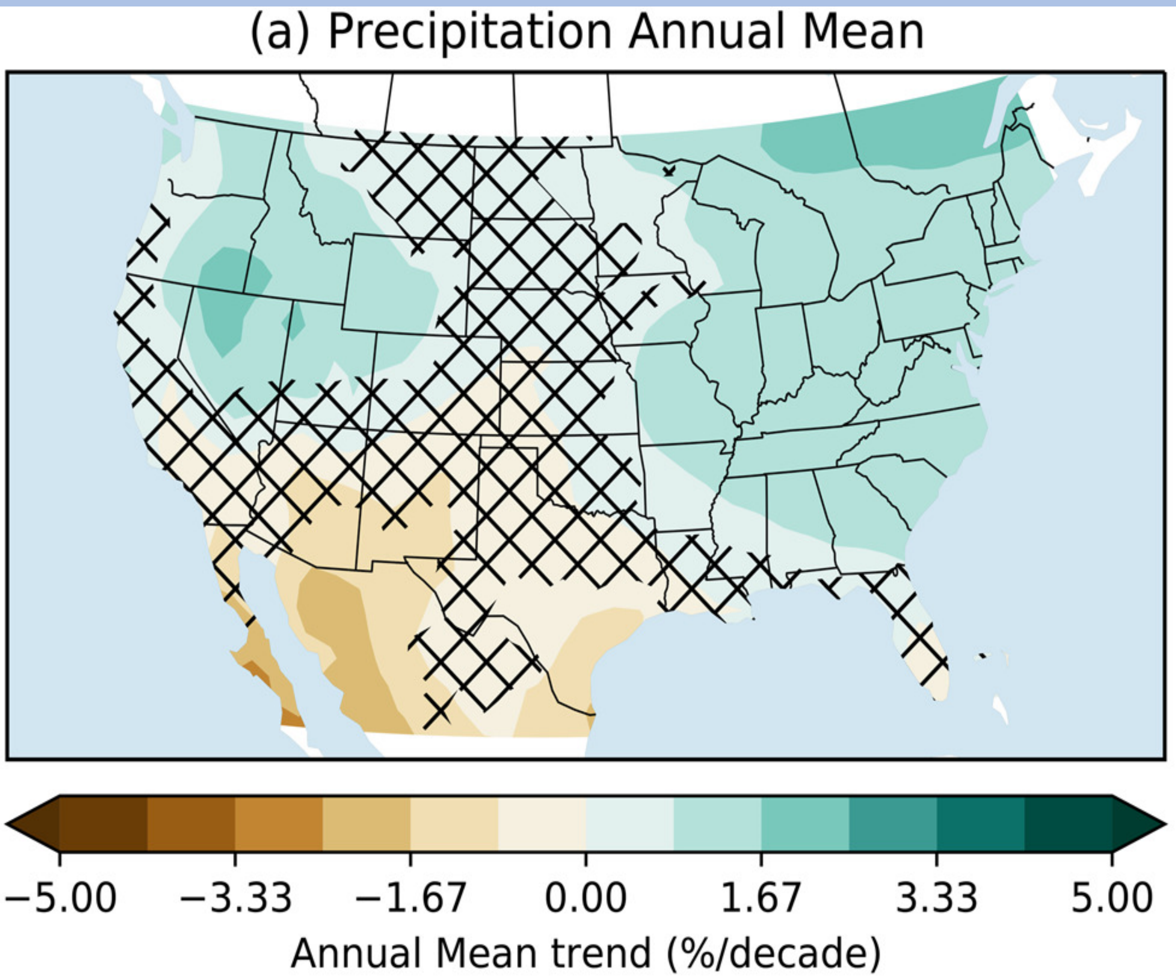
Supporting Information:
Supporting Information may be found in the online version of this article.

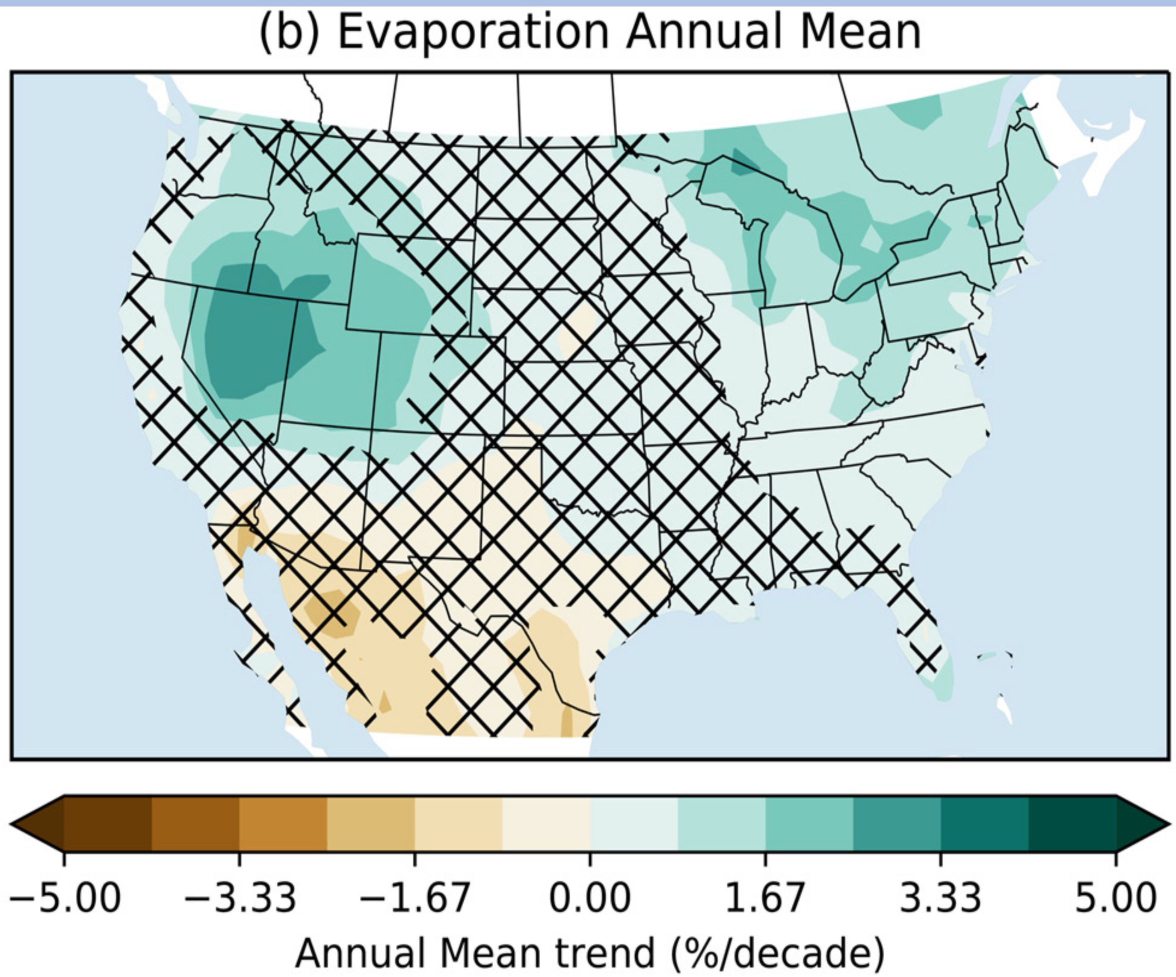
Projected Changes to Hydroclimate Seasonality in the Continental United States

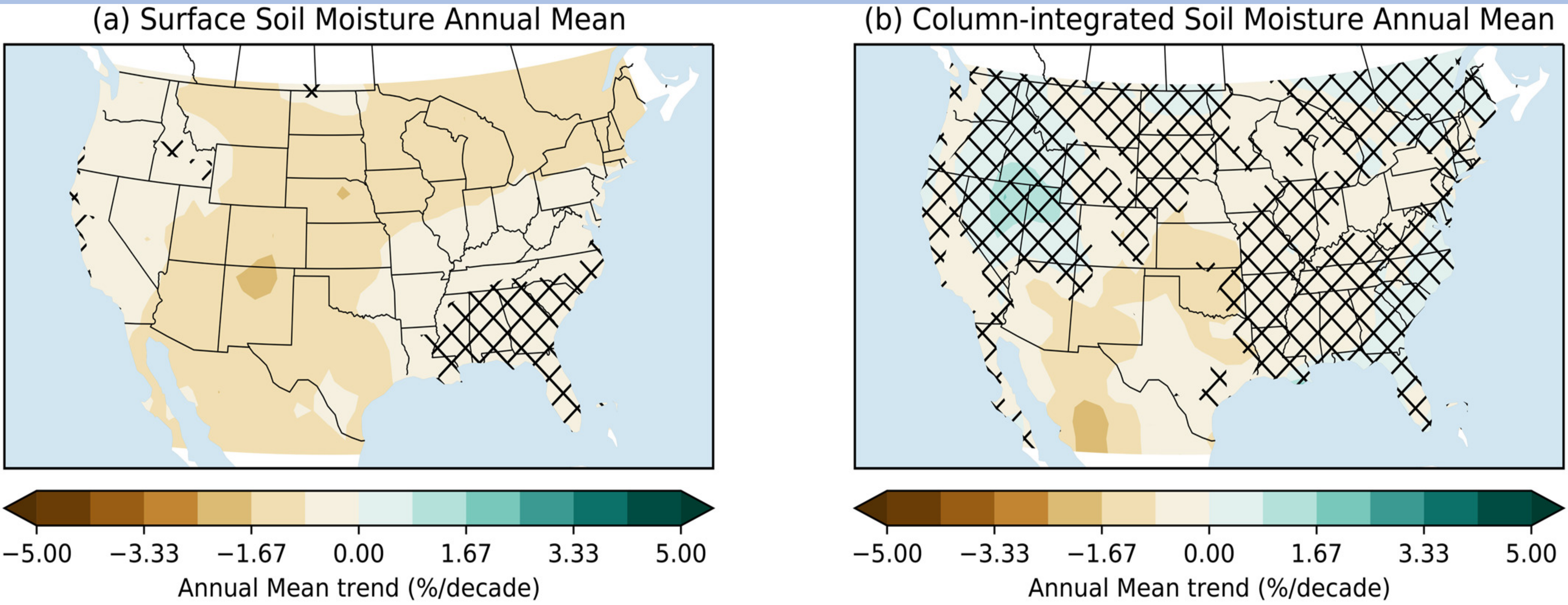
Kate Marvel[1,2], Benjamin I. Cook[1], Céline Bonfils[3], Jason E. Smerdon[4], A. Park Williams[4,5], and Haibo Liu[4]

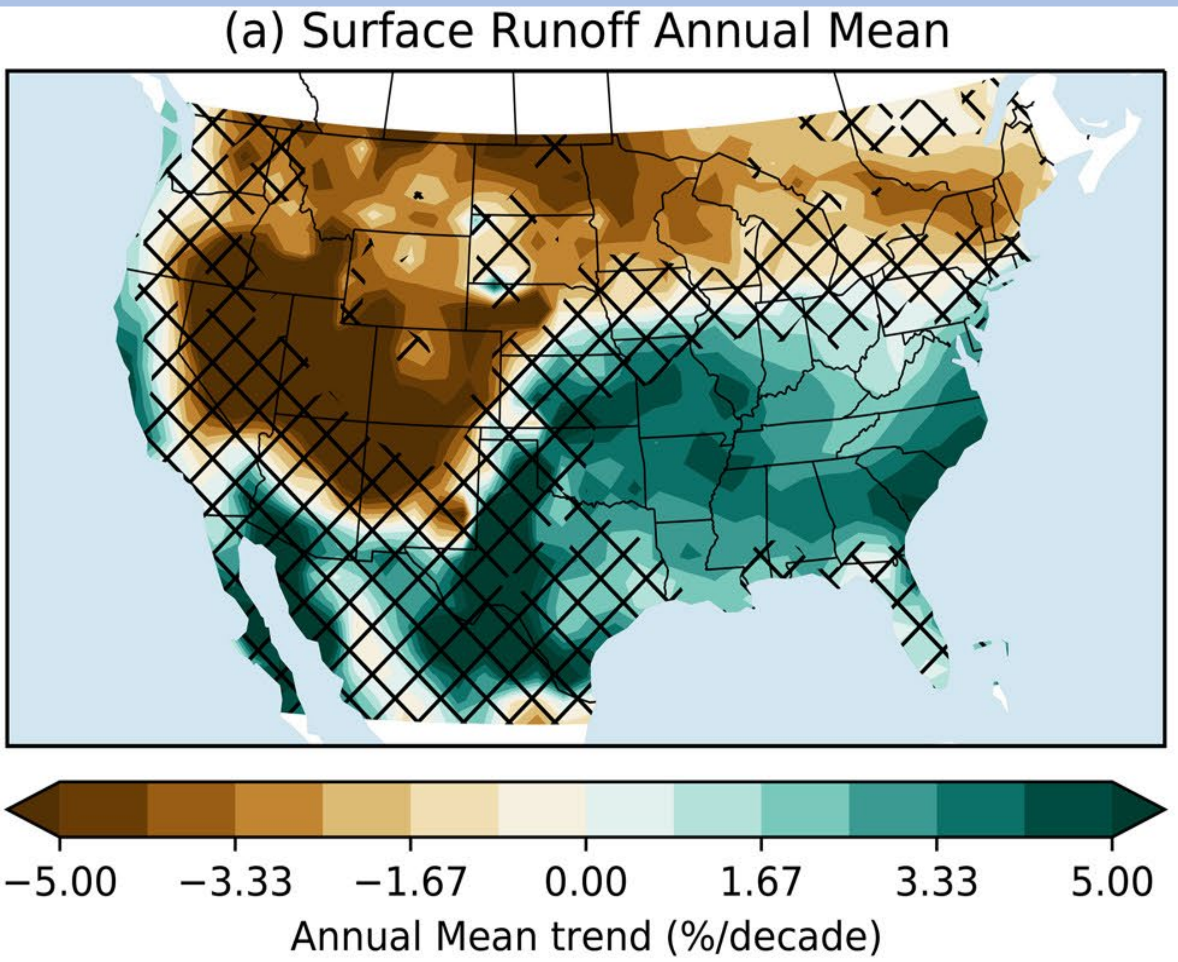
[1]NASA Goddard Institute for Space Studies, New York, NY, USA, [2]Center for Climate Systems Research, Columbia University, New York, NY, USA, [3]Lawrence Livermore National Laboratory, Livermore, CA, USA, [4]Lamont-Doherty Earth Observatory, Palisades, NY, USA, [5]Now at Department of Geography, University of California, Los Angeles, Los Angeles, CA, USA

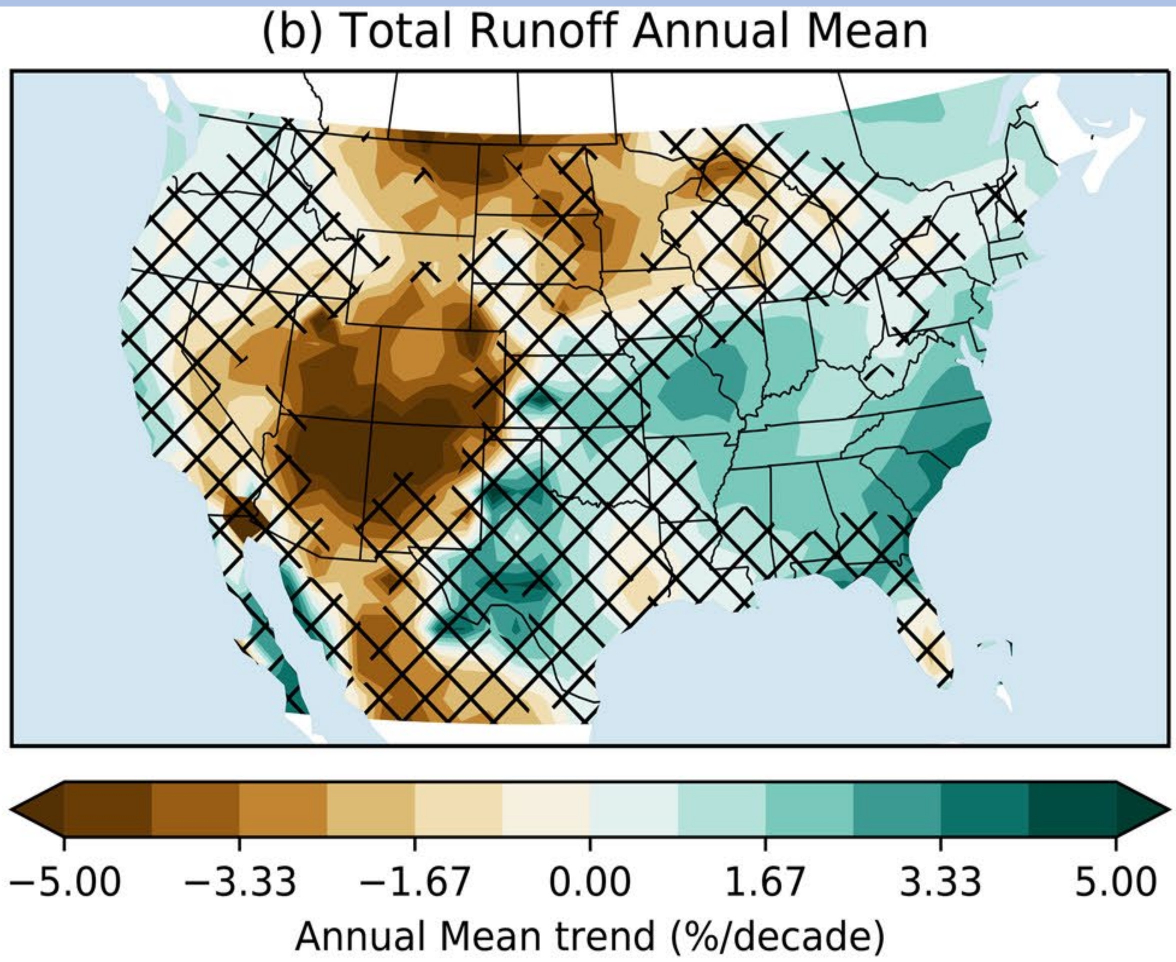
Abstract Future changes to the hydrological cycle are projected in a warming world, and any shifts in drought risk may prove extremely consequential for natural and human systems. In addition to long-term moistening, drying, or warming trends, perturbations to the annual cycle of regional hydroclimate variables may also have substantial impacts. We analyze projected changes in several hydroclimate variables across the continental United States, along with shifts in the amplitude and phase of their annual cycles. We find that even in regions where no robust change in the annual mean is expected, coherent changes to the annual cycle are projected. In particular, we identify robust regional phase shifts toward earlier arrival of peak evaporation in the northern regions, and peak runoff and total soil moisture in the western regions. Changes in the amplitude of the annual cycle of total and surface soil moisture are also projected, and reflect changes to the annual cycle in surface water supply and demand. Whether


(a) Precipitation Annual Mean
−5.00
−3.33
−1.67
0.00
1.67
3.33
5.00
Annual Mean trend (%/decade)


(b) Evaporation Annual Mean
−5.00
−3.33
−1.67
0.00
1.67
3.33
5.00
Annual Mean trend (%/decade)


(a) Surface Soil Moisture Annual Mean
(b) Column-integrated Soil Moisture Annual Mean
−5.00
−3.33
−1.67
0.00
1.67
3.33
5.00
Annual Mean trend (%/decade)
−5.00
−3.33
−1.67
0.00
1.67
3.33
5.00
Annual Mean trend (%/decade)


(a) Surface Runoff Annual Mean
−5.00
−3.33
−1.67
0.00
1.67
3.33
5.00
Annual Mean trend (%/decade)


(b) Total Runoff Annual Mean
−5.00
−3.33
−1.67
0.00
1.67
3.33
5.00
Annual Mean trend (%/decade)

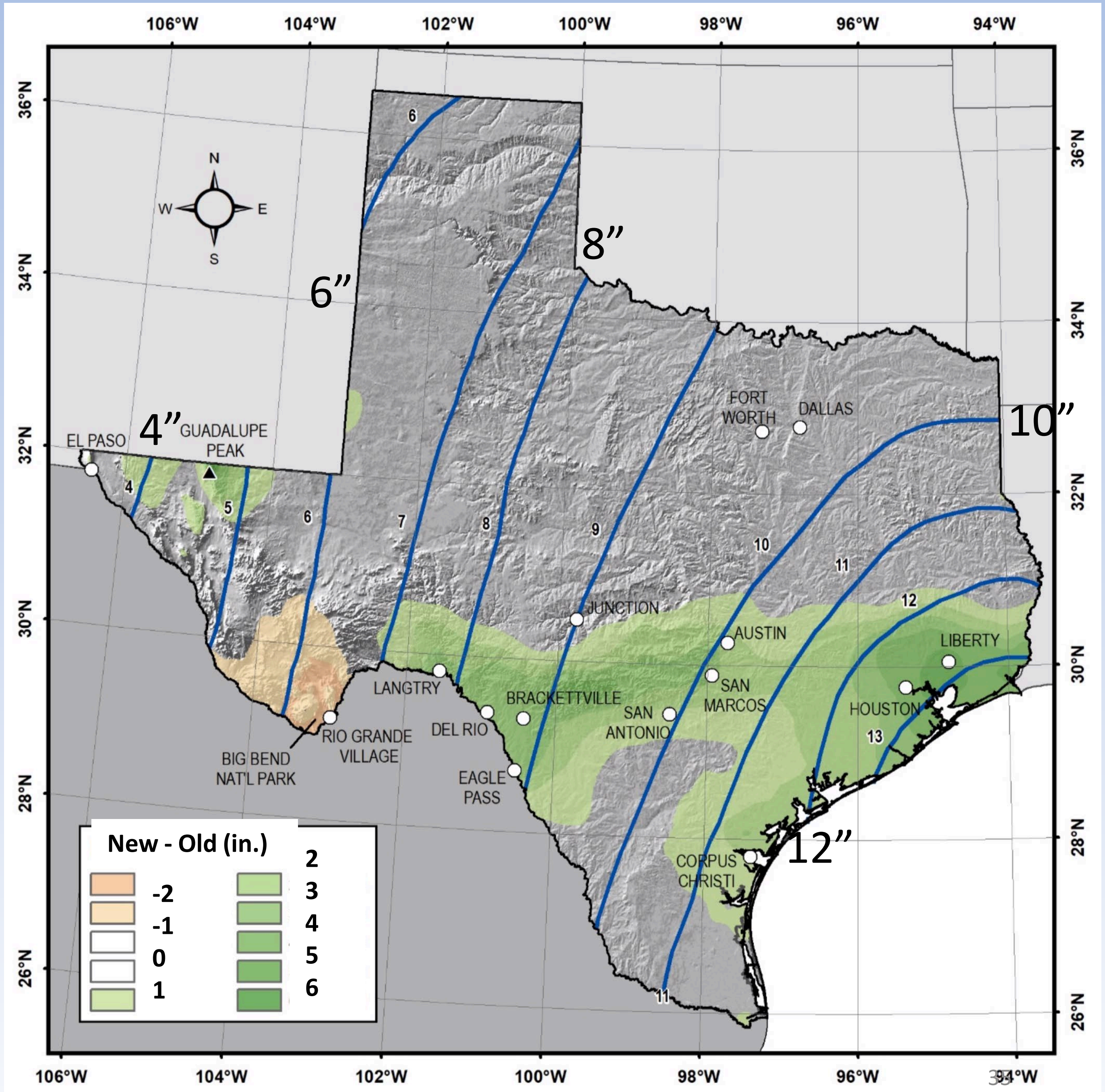
What about really heavy rain?

(research funded by Harris County Flood Control District)

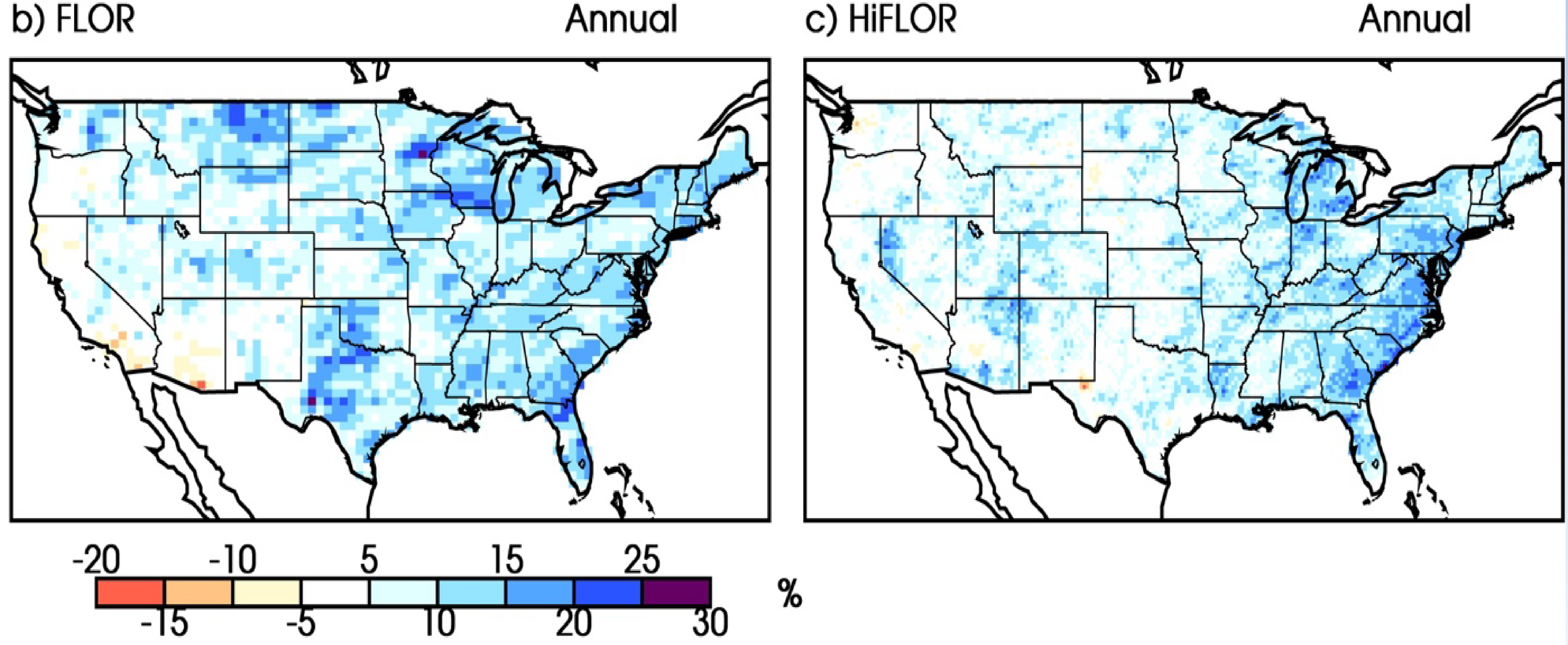
(additional work by Savannah Jorgensen)

(paper to be submitted very soon)

- 2018: NOAA Atlas 14: Official estimates of extreme rainfall risk (100-yr events, etc.)
- Analysis includes 2017 rainfall
- Previous analysis dates from 1960s
- Old analysis (contours) and change (shading) in 1-day 100-yr rainfall amounts shown at right

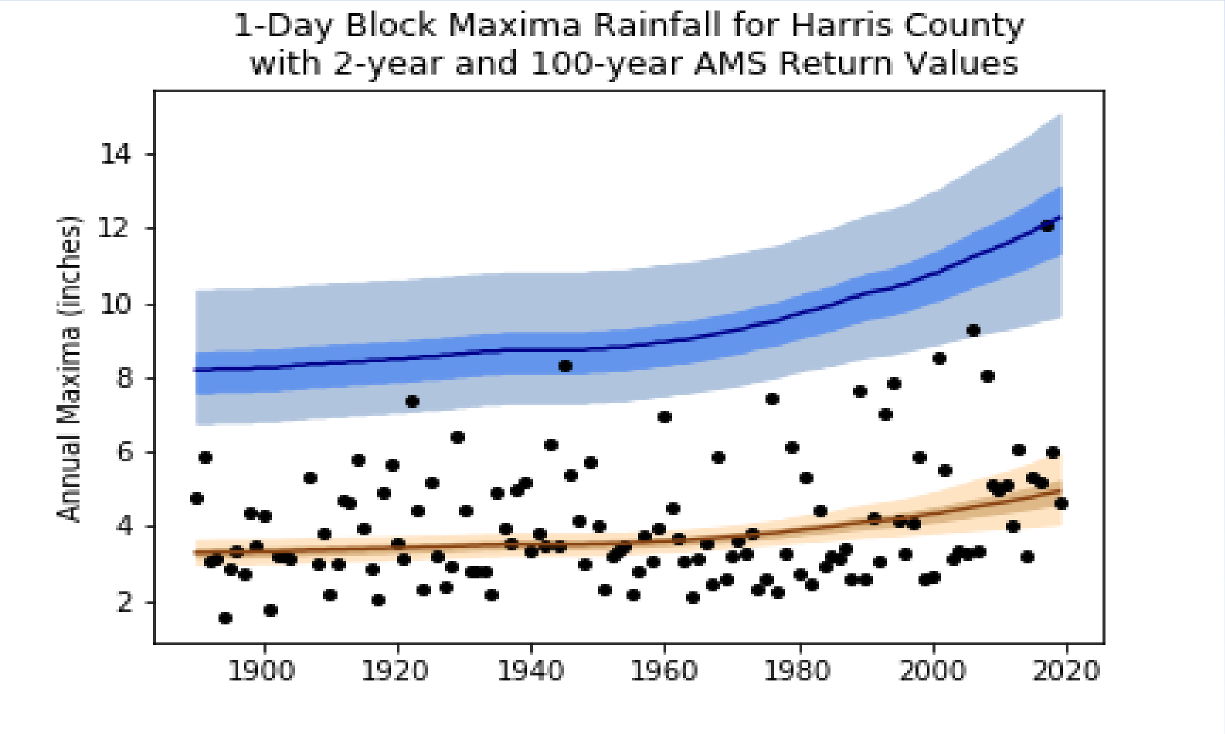


Models predict increases, but…

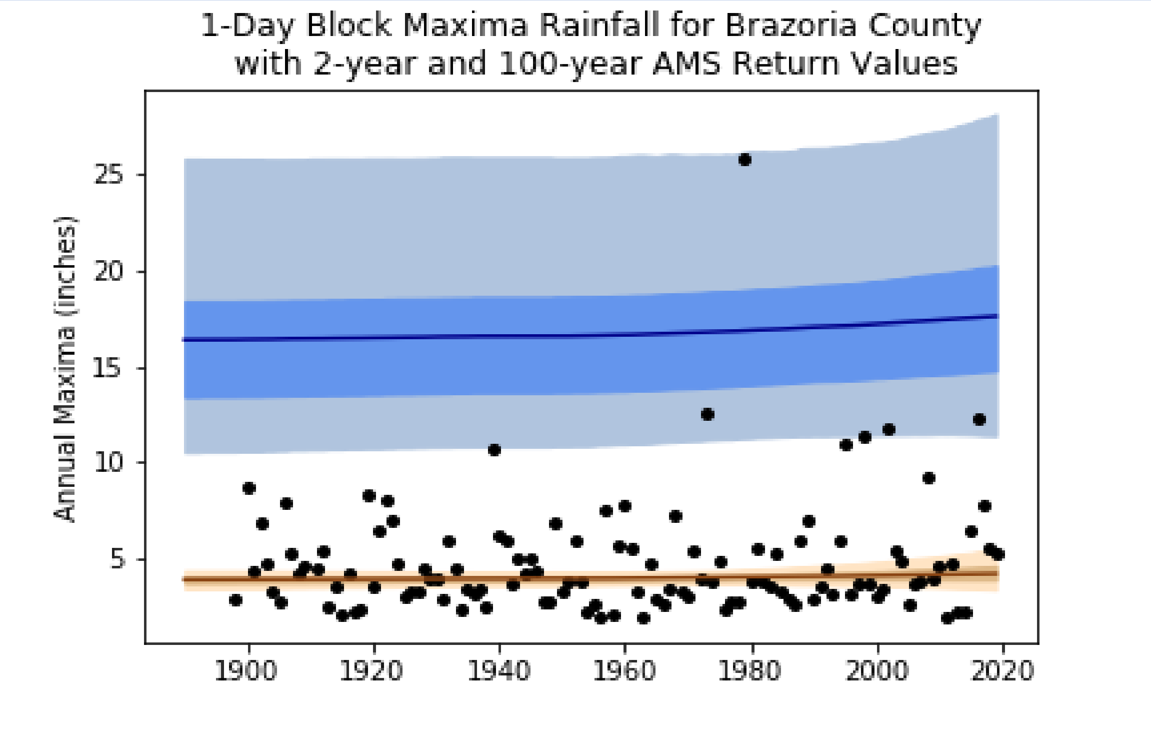


Van der Weil et al. (2016)

Your Experience May Vary

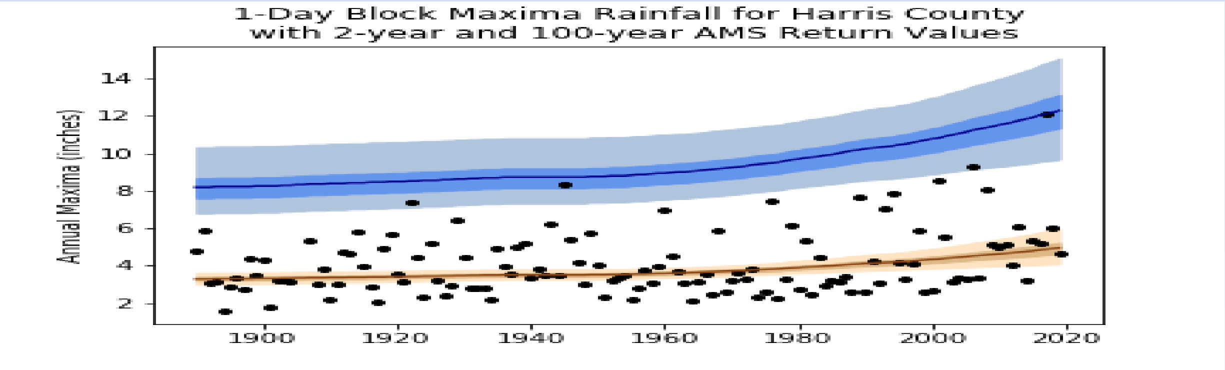


Harris County single-station composite

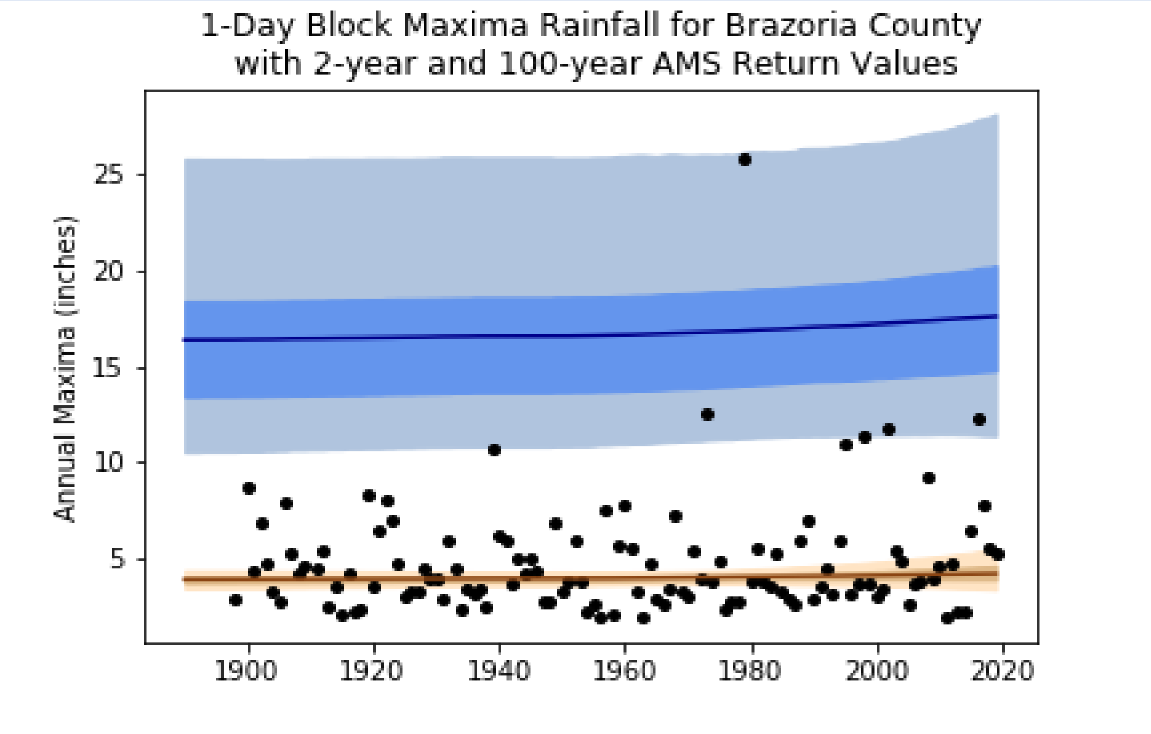


Brazoria County single-station composite

Your Experience May Vary

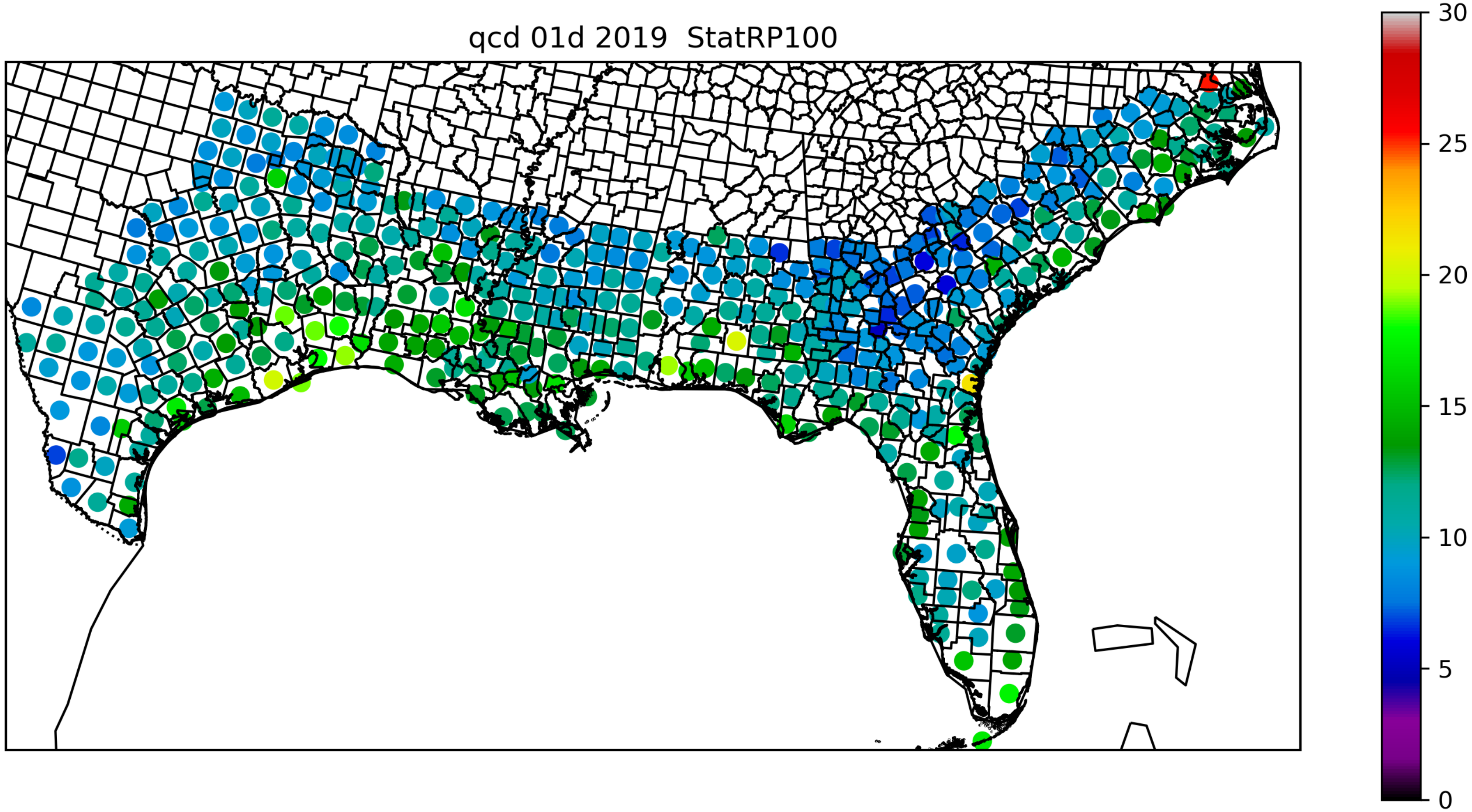


Harris County single-station composite

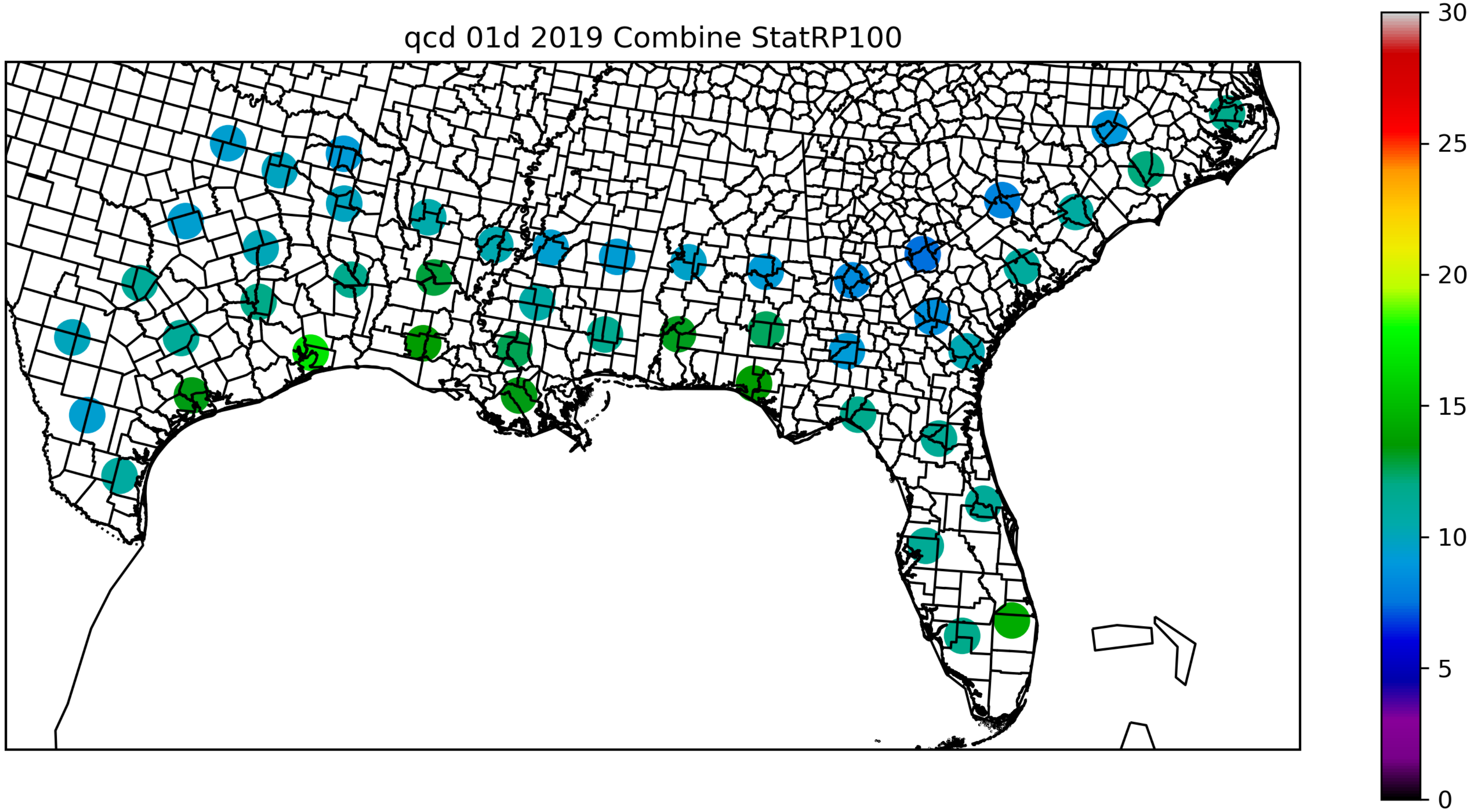


Brazoria County single-station composite

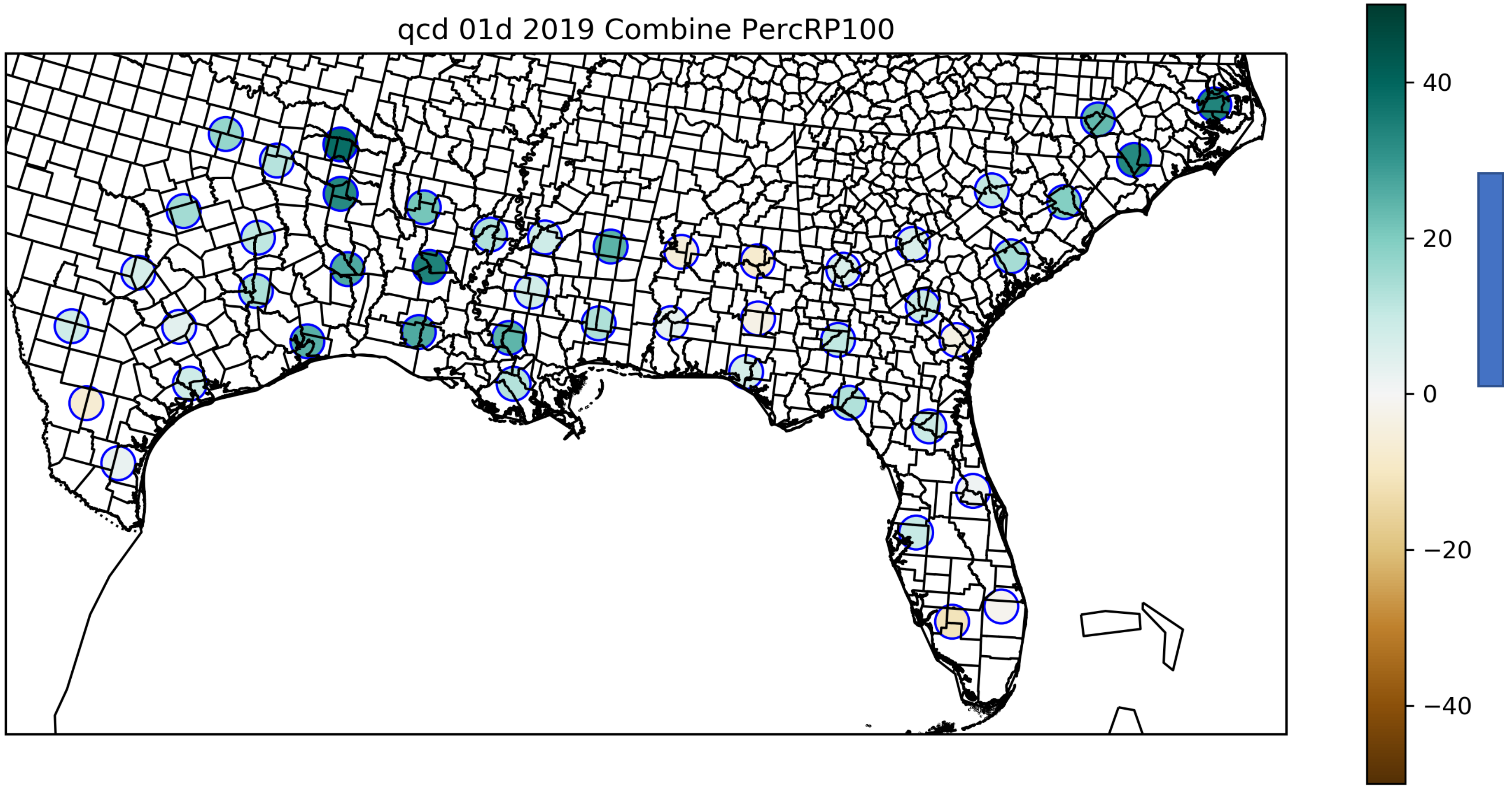
Stationary Return Values (in.)



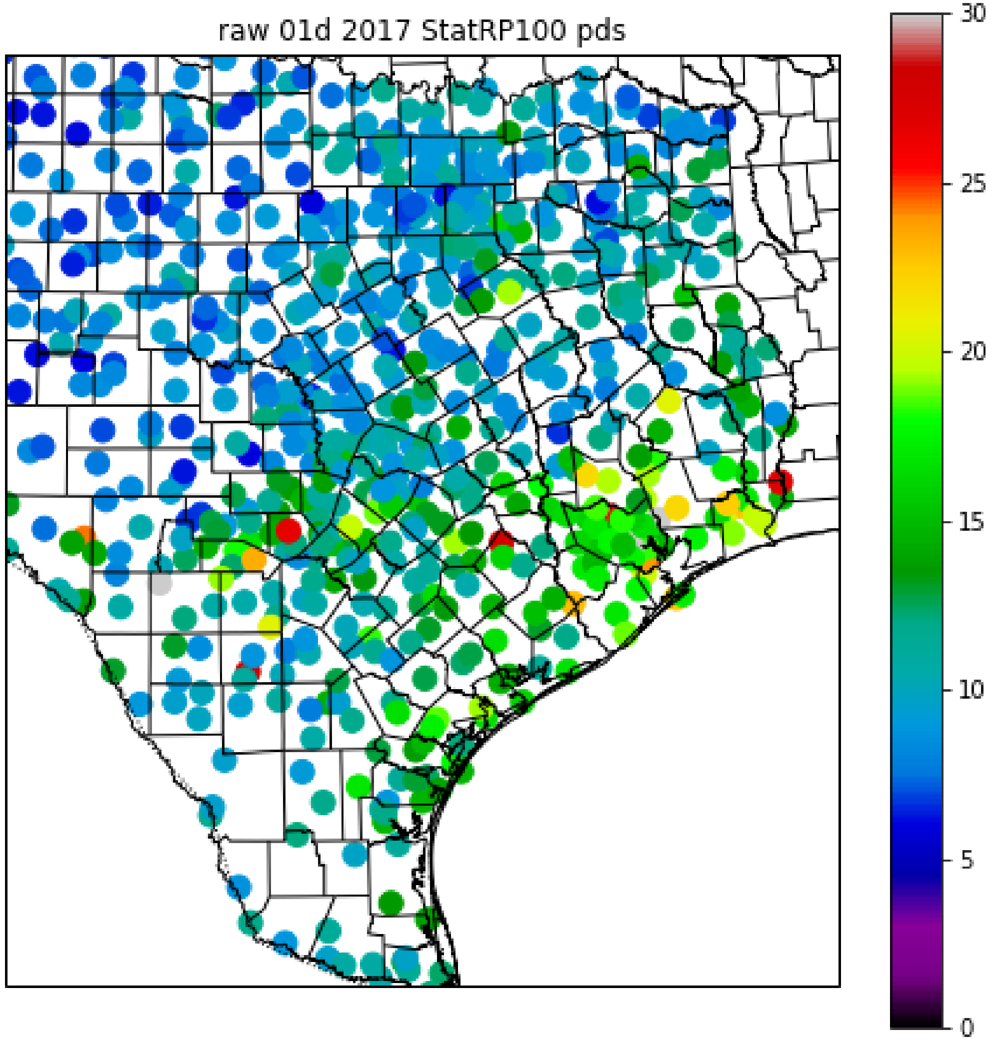
Stationary Return Values (in.)



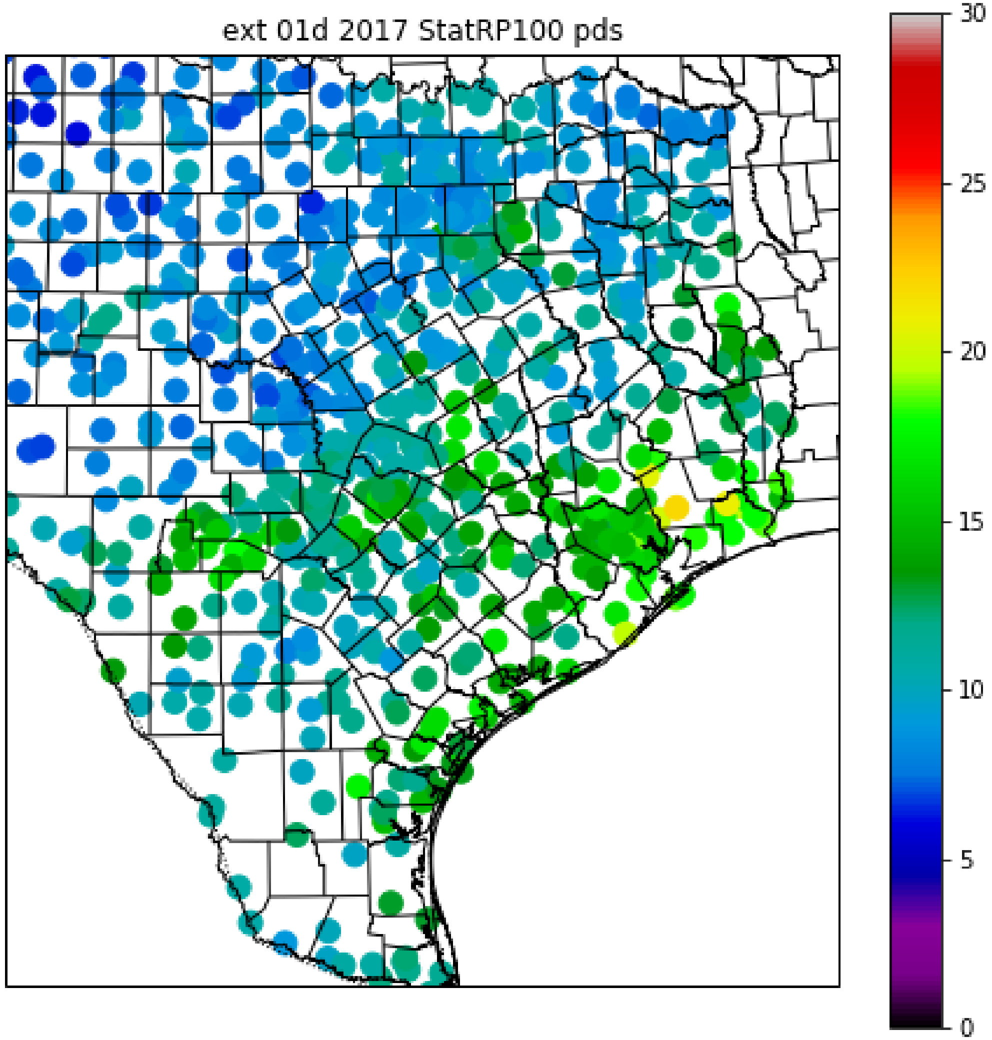
Return Value Trend, 1960-2020 (%)



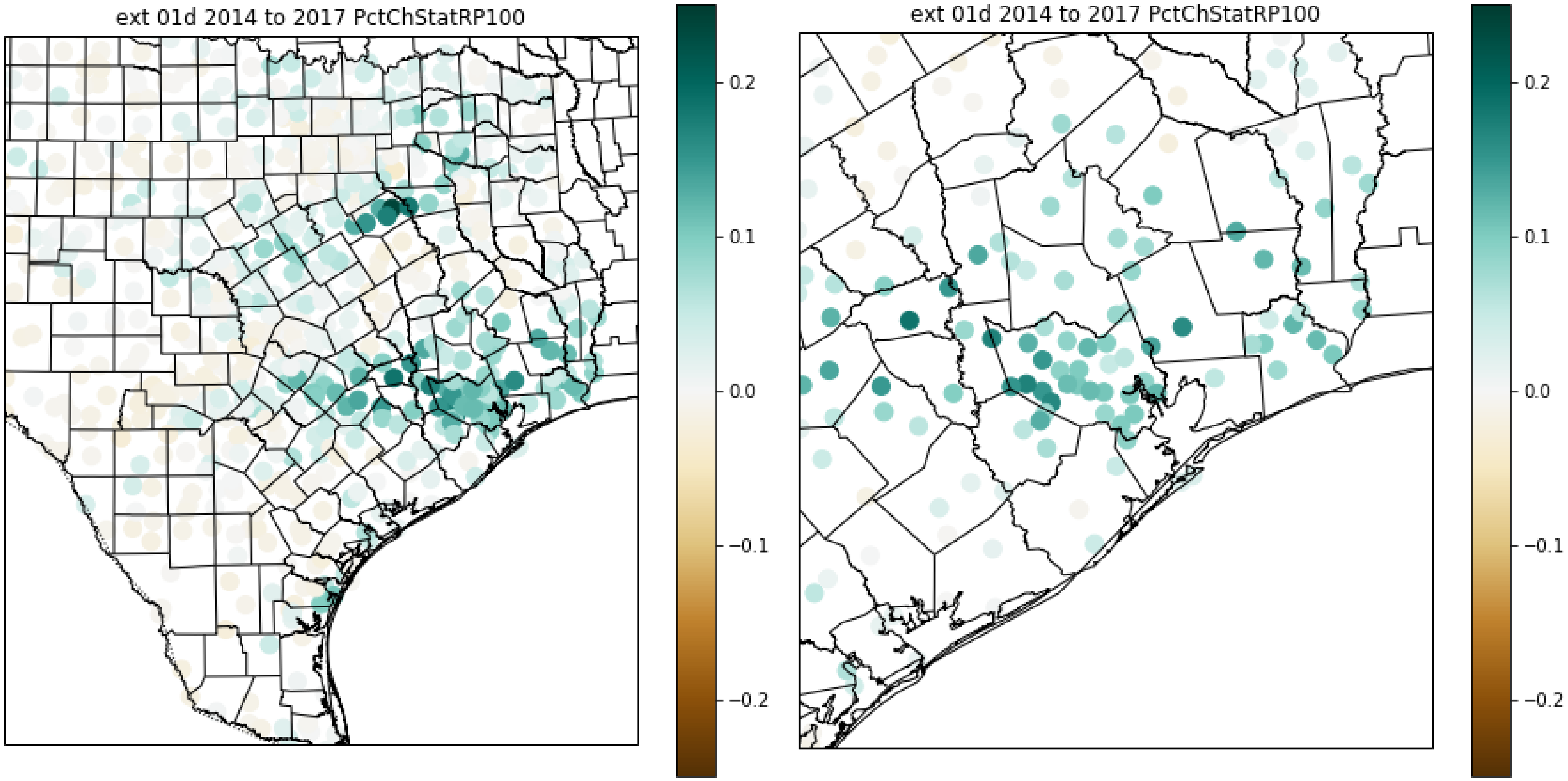
100-year 1-day amount (inches)



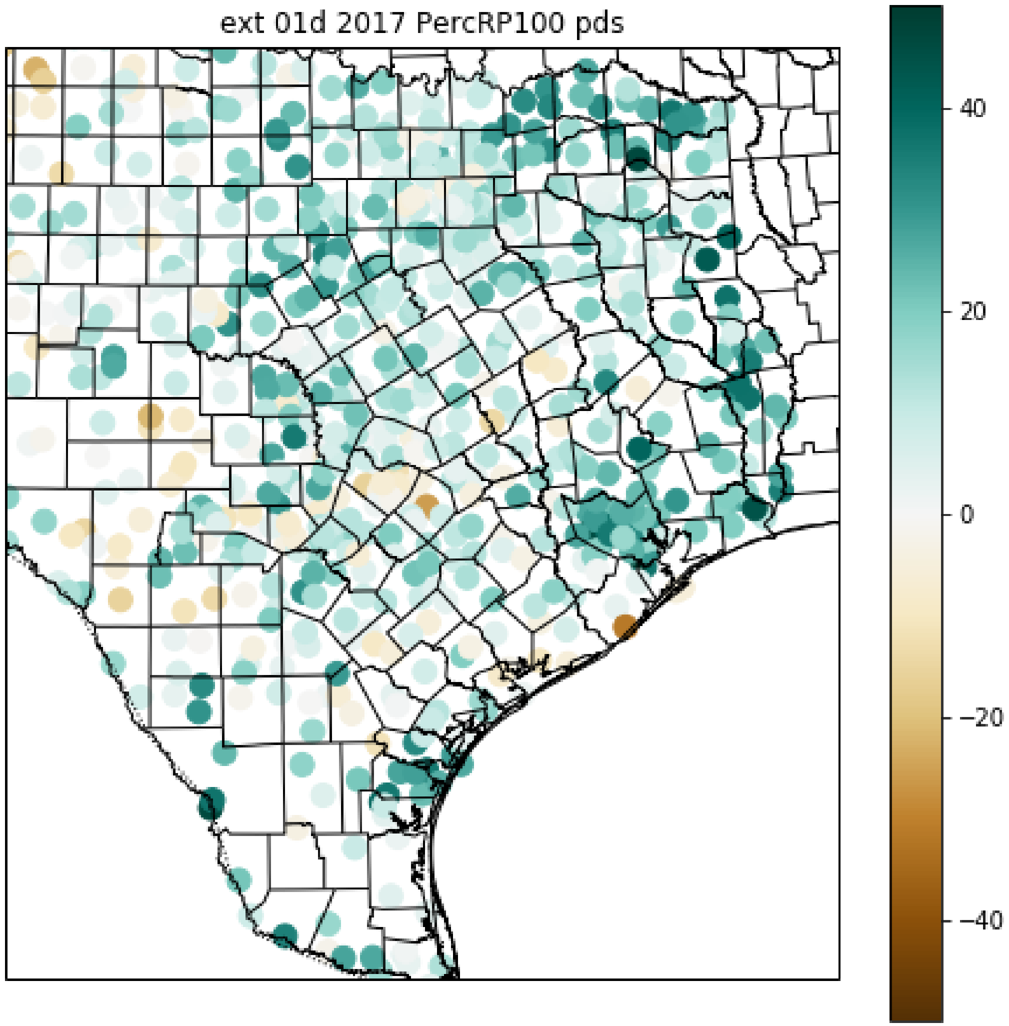
Original Atlas 14 data



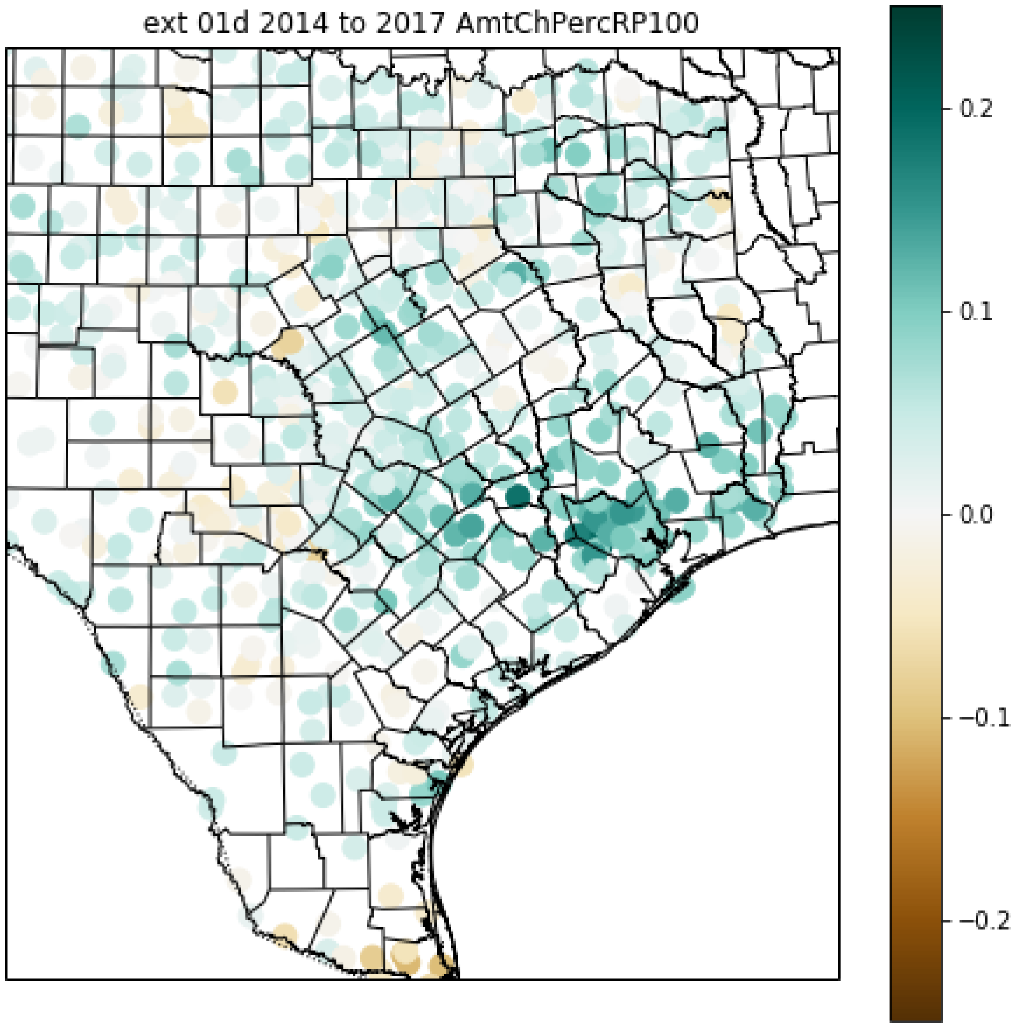
Extended Atlas 14 data



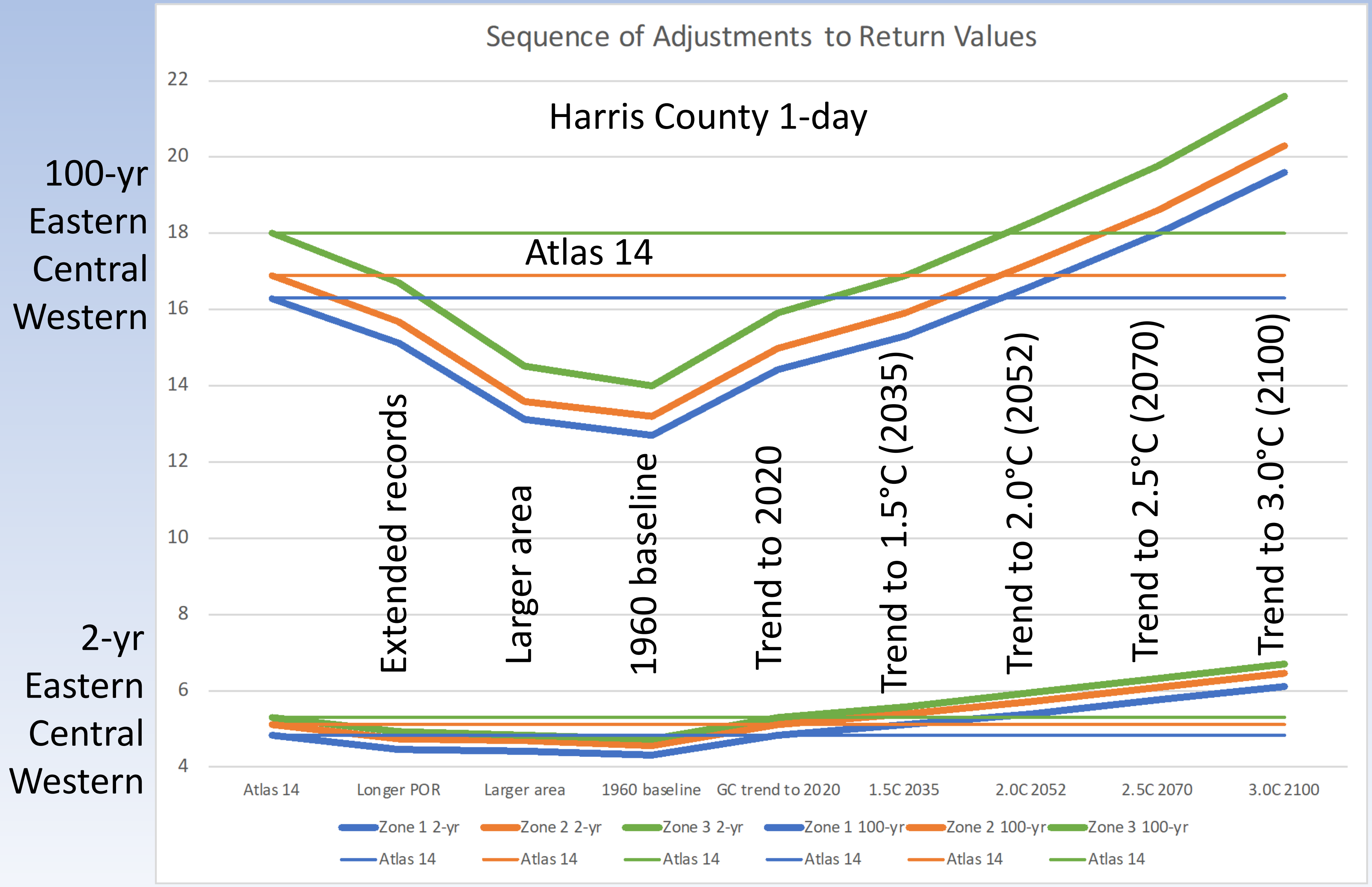
Fractional effect of 2015-2017 events on stationary return value



Nonstationary trend (%), 1960-2020



Effect of 2015-2017 events on trend (fraction of return value)



Sequence of Adjustments to Return Values
Harris County 1-day
Atlas 14
100-yr
Eastern
Central
Western
2-yr
Eastern
Central
Western
22
20
18
16
14
12
10
8
6
4
Extended records
Larger area
1960 baseline
Trend to 2020
Trend to 1.5°C (2035)
Trend to 2.0°C (2052)
Trend to 2.5°C (2070)
Trend to 3.0°C (2100)
Atlas 14
Longer POR
Larger area
1960 baseline
GC trend to 2020
1.5C 2035
2.0C 2052
2.5C 2070
3.0C 2100
Zone 1 2-yr
Zone 2 2-yr
Zone 3 2-yr
Zone 1 100-yr
Zone 2 100-yr
Zone 3 100-yr
Atlas 14
Atlas 14
Atlas 14
Atlas 14
Atlas 14
Atlas 14

Summary

- Soils getting drier: probably
- Runoff increasing: maybe
- Lake evaporation increasing: definitely
- Extreme rainfall increasing: yes
- Note: extreme rainfall and runoff trends are what should happen relative to what should have happened, not what actually happened

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Summary

- Soils getting drier: probably
- Runoff increasing: maybe
- Lake evaporation increasing: definitely
- Extreme rainfall increasing: yes
- Note: extreme rainfall and runoff trends are what should happen relative to what should have happened, not what actually happened
- How large are these changes? I wish I could tell you!

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Questions?

Wrap-Up

- If you submitted an RSVP for this webinar, you will receive an email with the presentation slides and a subsequent email with a link to the recording. The slides will be posted under the green banner "Webinars" here:

https://www.nctcog.org/envir/natural-resources/water-resources

- If you did not RSVP and would like these webinar materials, please email eberg@nctcog.org to be included in the follow-up emails or type your email address in the chat.

North Central Texas Council of Governments

Thank you for attending!

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Environment & Development

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