Observed and projected physical climate change in the Mississippi River watershed

December 3, 2019

Renewable Natural Resources Foundation -- Congress on Charting a New Course for the Mississippi River Watershed

Dan Barrie, NOAA Climate Program Office

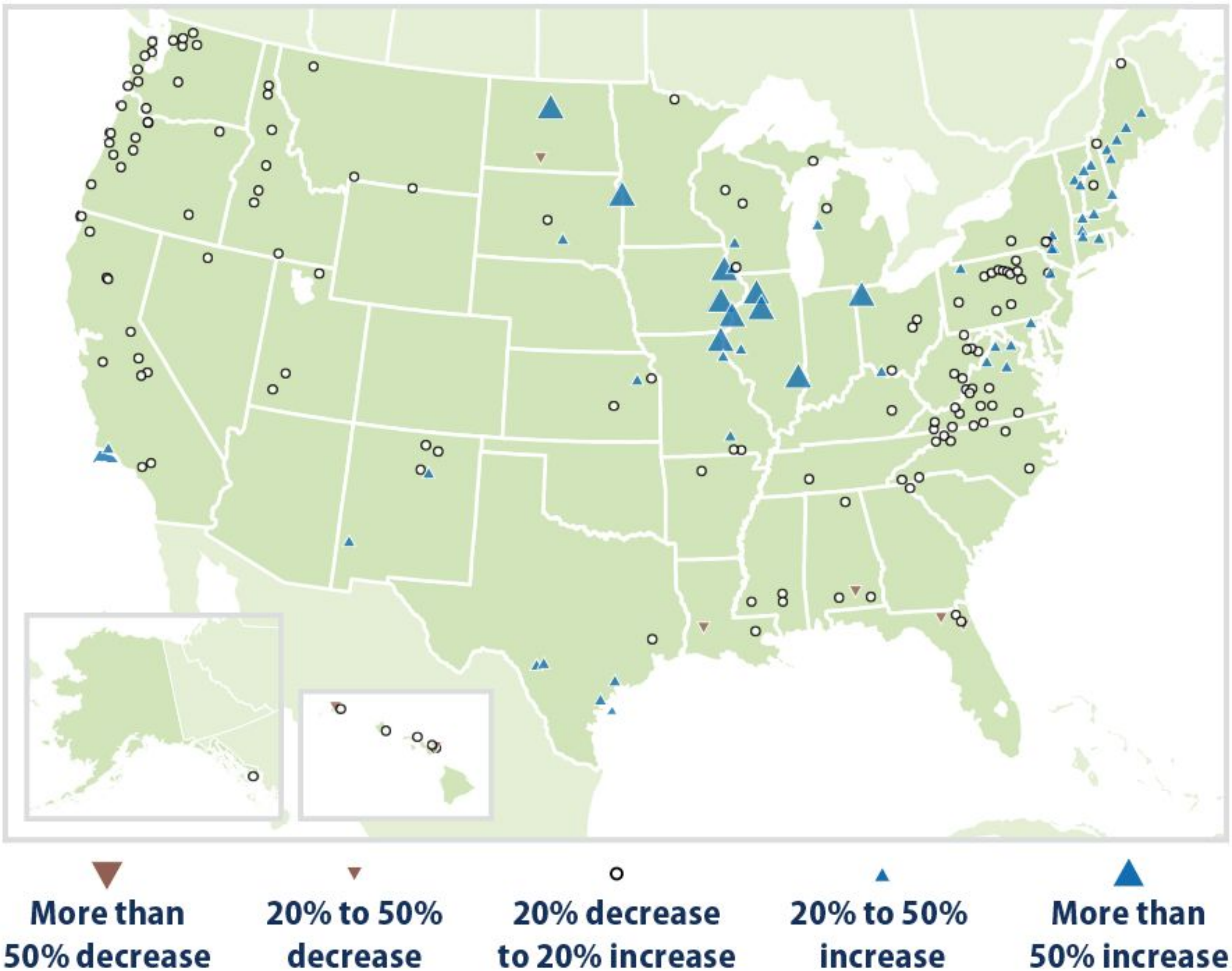
https://earthobservatory.nasa.gov/images/145029/flooding-continues-along-the-mississippi

The present: ↑ Precipitation ↑ Extreme Precipitation ↓ Snow cover ↑ Soil Moisture ↑ Streamflow ↑ Flooding (regionally).

The future: many trends continuing. Balance between decreasing snow, decreasing soil moisture, more extreme precipitation complex for Mississippi.

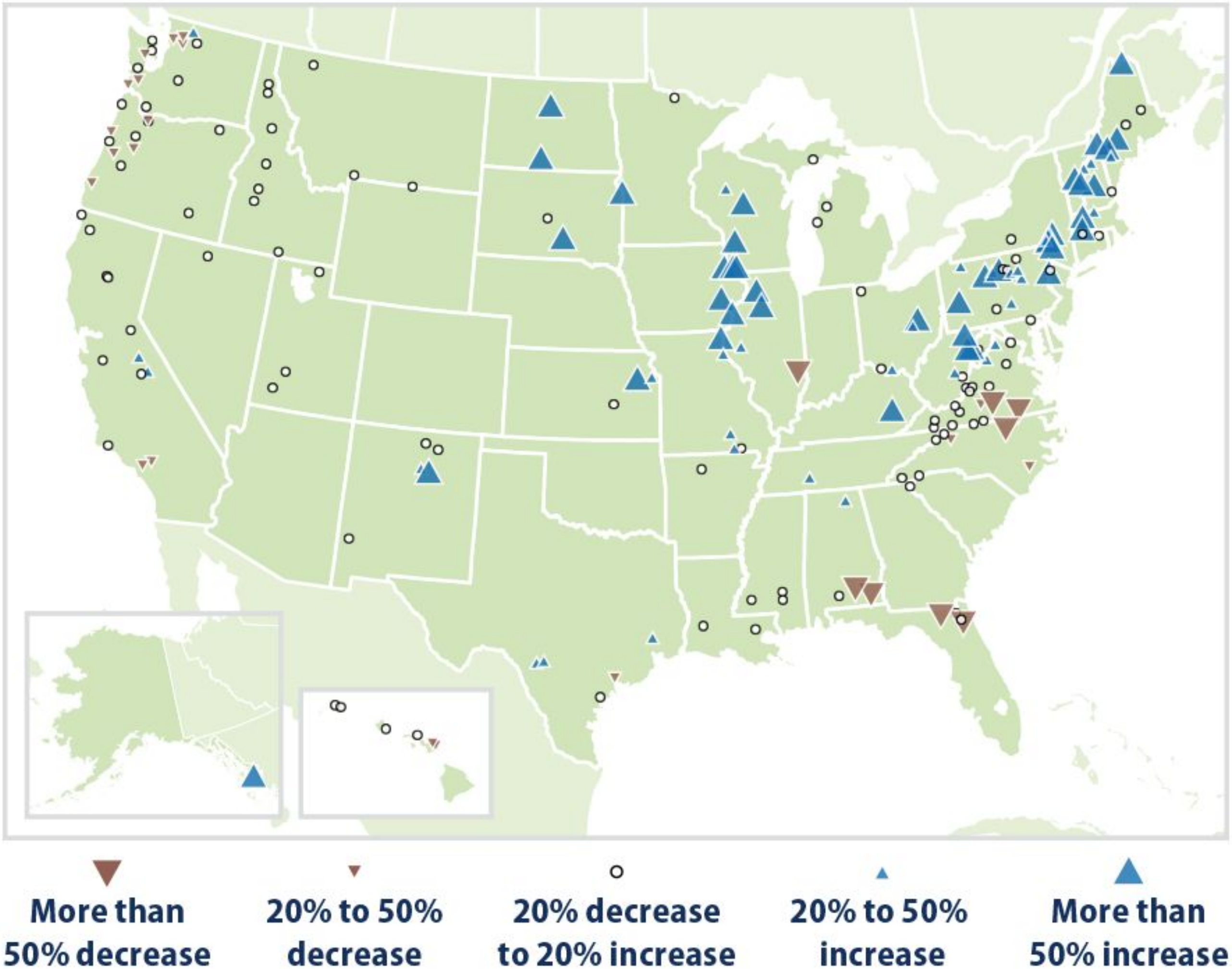
https://svs.gsfc.nasa.gov/4493

Annual Average Streamflow in the United States, 1940–2014



https://www.epa.gov/climate-indicators/climate-change-indicators-streamflow

Seven-Day Low Streamflows in the United States, 1940–2014



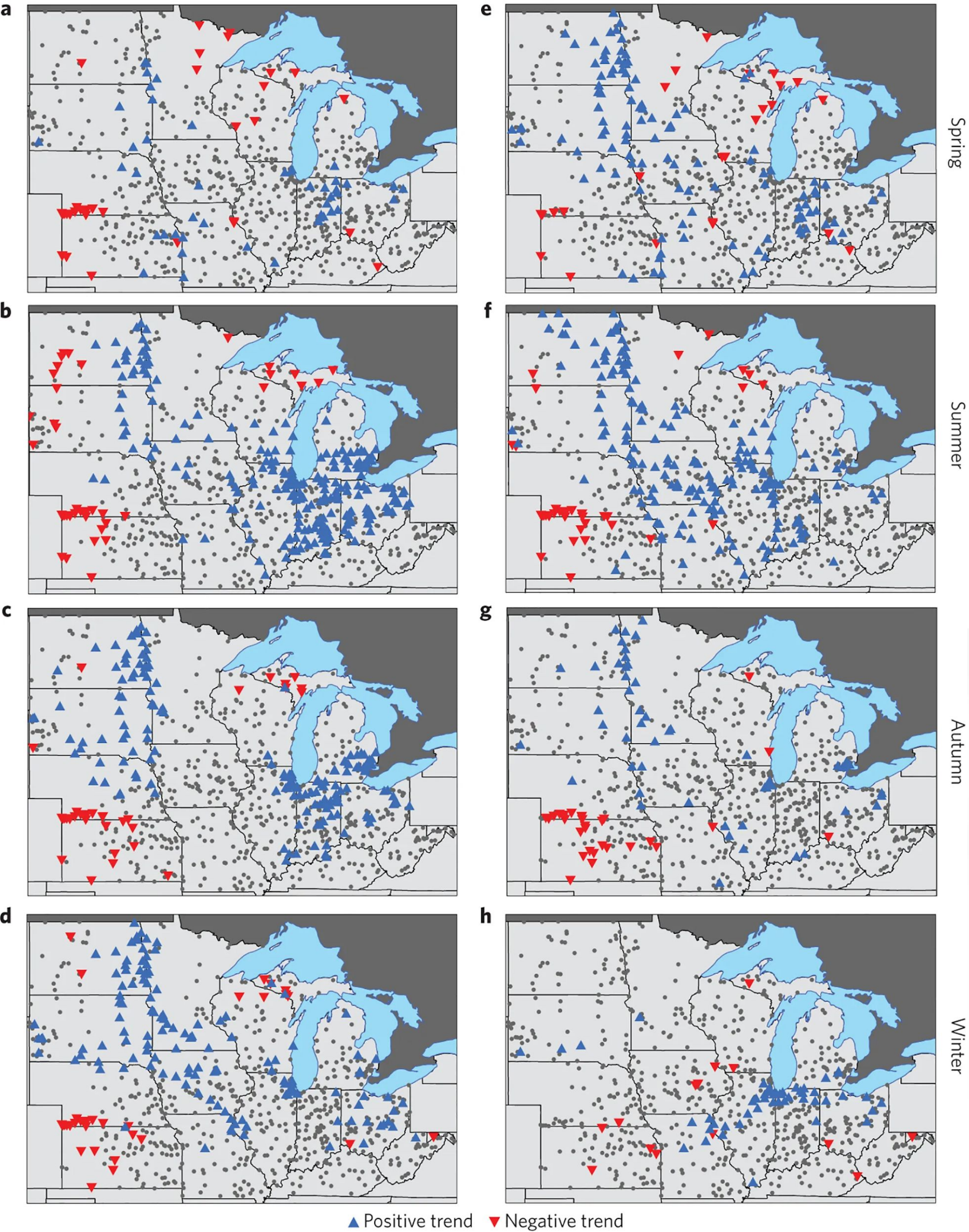
Fourth National Climate Assessment, Volume I (2017):

"Annual maximum streamflow shows statistically significant [increasing] trends in the upper Mississippi River valley."

"[A]cross the midwestern United States, statistically significant increases in flooding are well documented."

https://www.epa.gov/climate-indicators/climate-change-indicators-streamflow

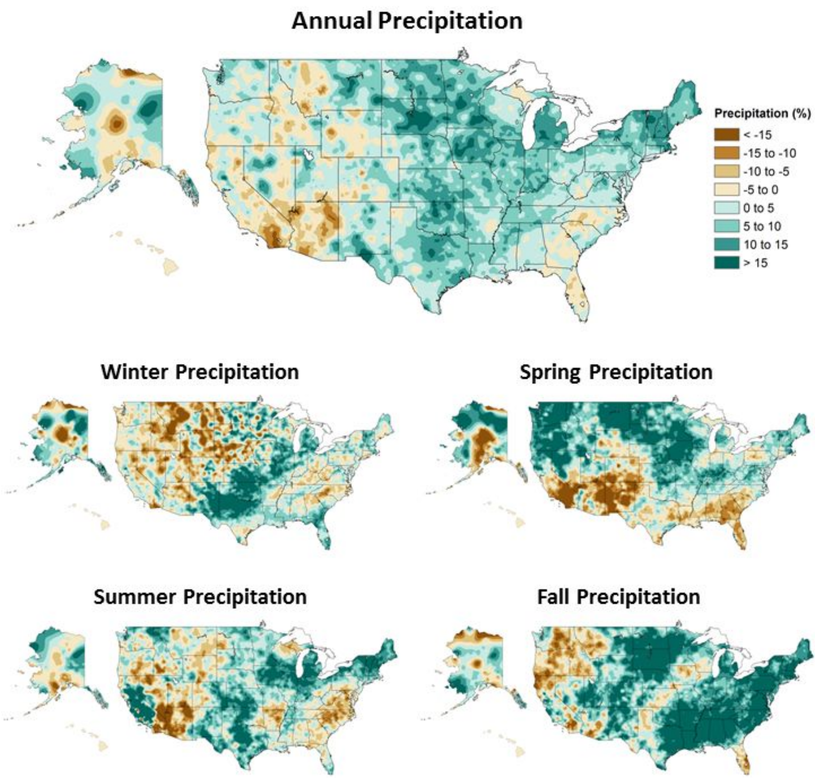
Seasonal change in the Magnitude (left) and Frequency (right) of River Flooding in the United States, 1962–2011

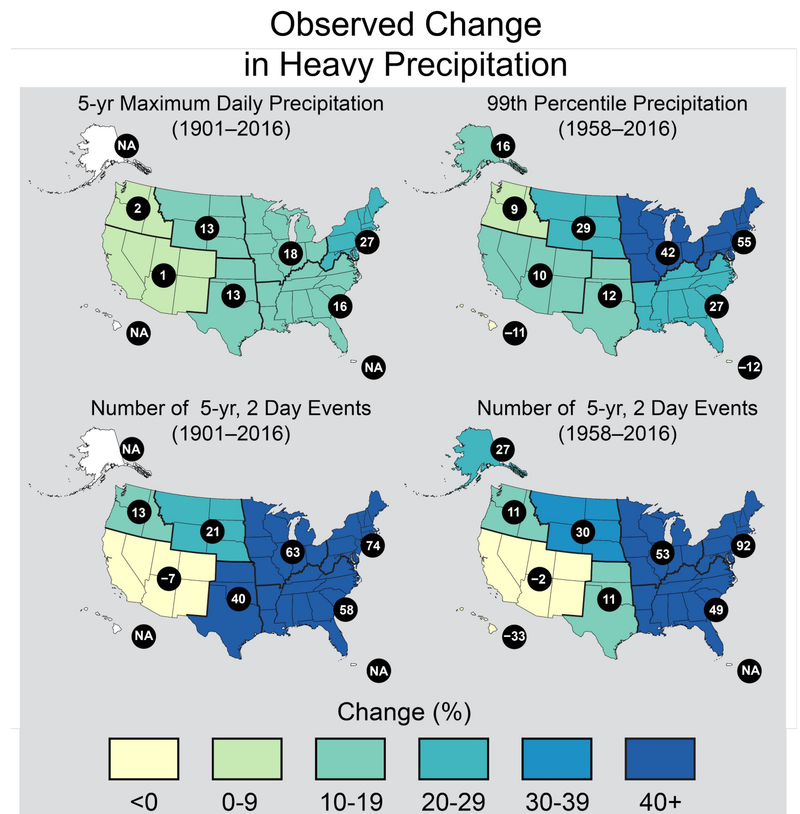


Mallakpour, I., and G. Villarini, 2015: The changing nature of flooding across the central United States. Nature Climate Change, 5, 250–254, doi:10.1038/nclimate2516.

https://dnr.mo.gov/geology/wrc/interstatewaters.htm

Observed change in mean and extreme precipitation



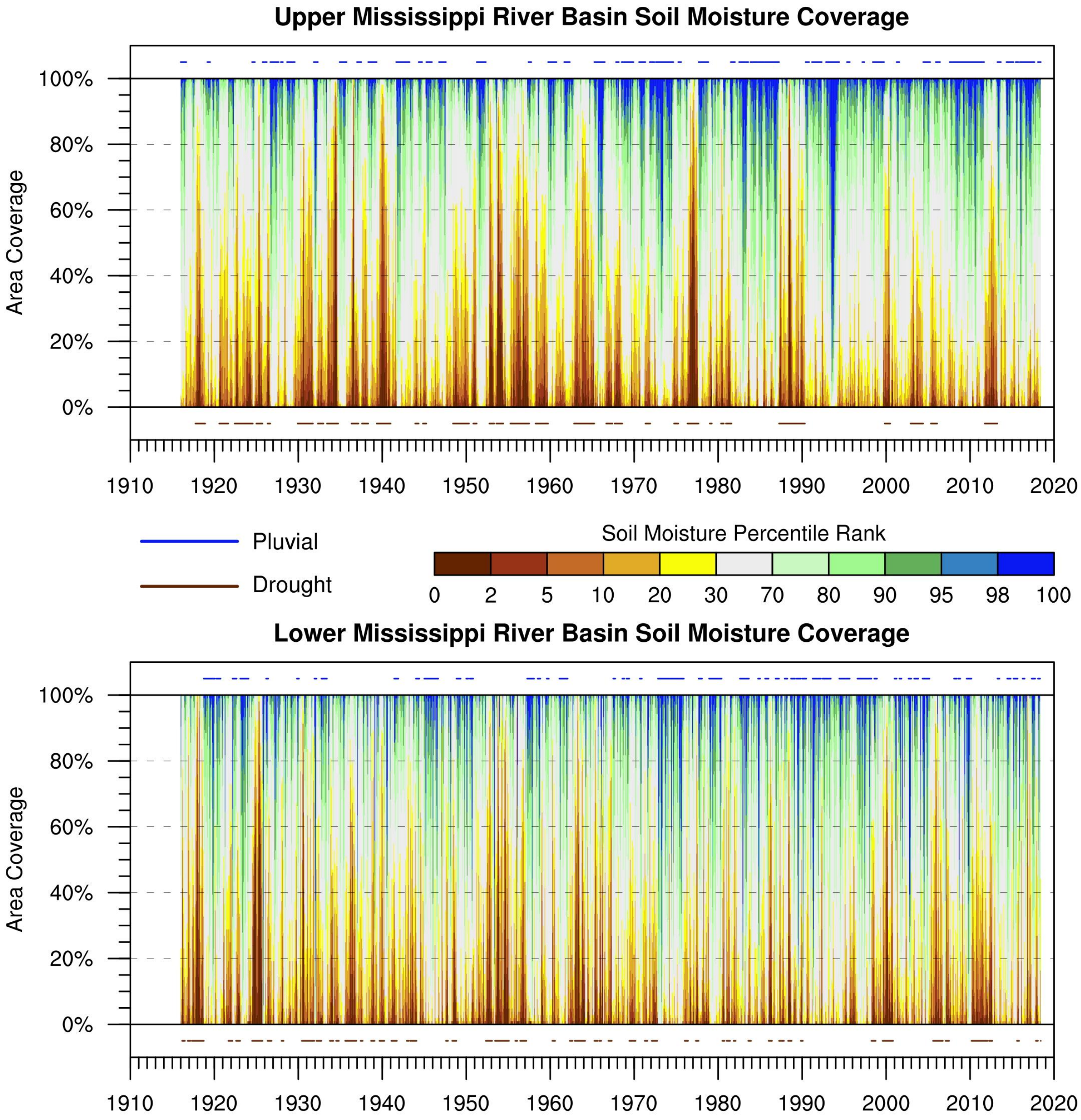


Fourth National Climate Assessment, Volume I (2017):

"...across the midwestern United States, statistically significant increases in flooding are well documented. These increases in flood risk and severity are not attributed to 20th century changes in agricultural practices, but instead are attributed mostly to the observed increases in precipitation."

Fourth National Climate Assessment, Volume I, Climate Science Special Report: Figures 7.1 and 7.4

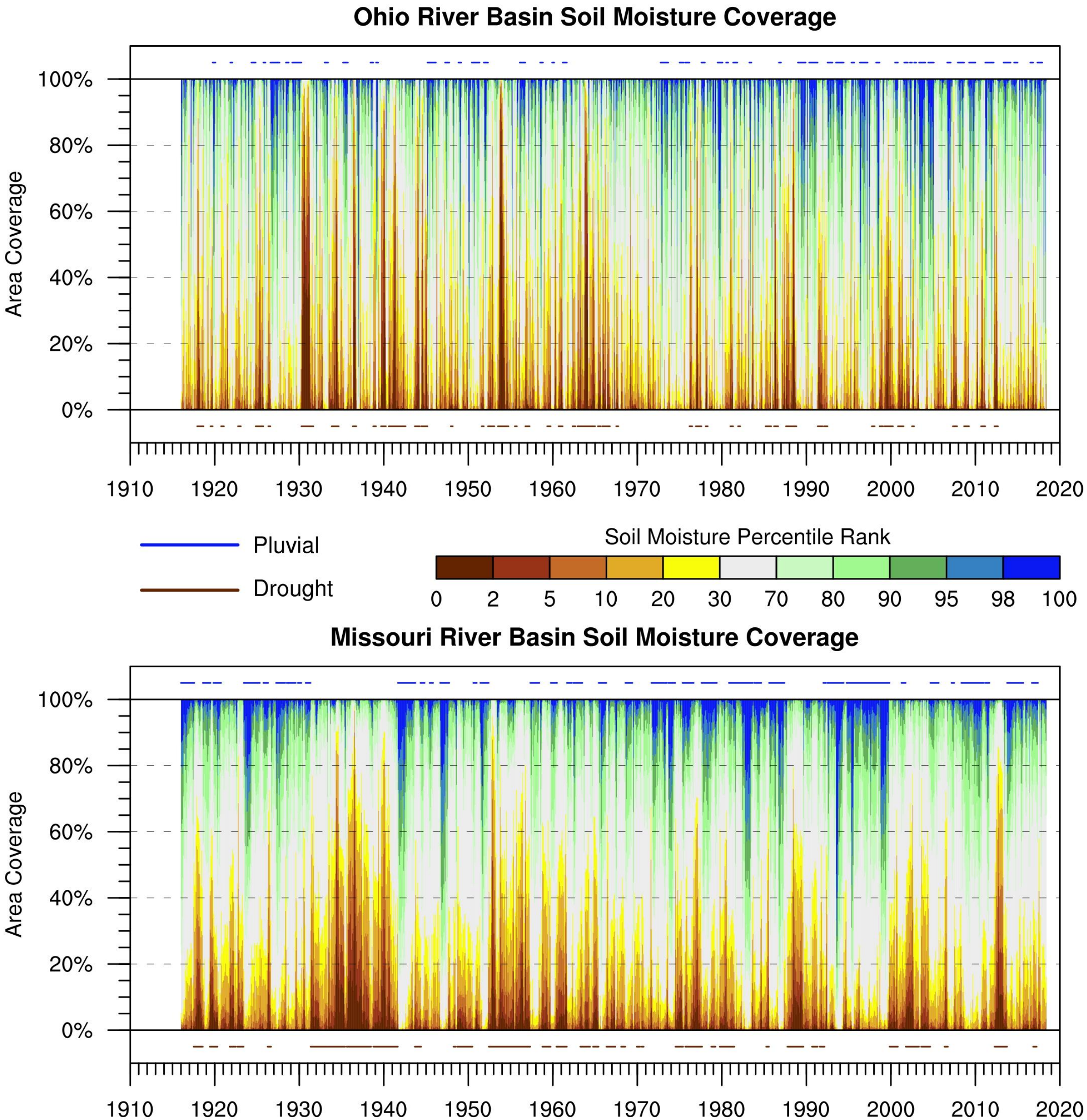
Soil Moisture in Mississippi Basin



- The Upper Mississippi (UM) exhibits epochal behavior for soil moisture -- pluvial and drought periods with variability on interannual and decadal time scales.
- The Lower Mississippi shows faster variability.

Figures courtesy Andy Hoell and Marty Hoerling (NOAA ESRL)

Soil Moisture in Mississippi Basin

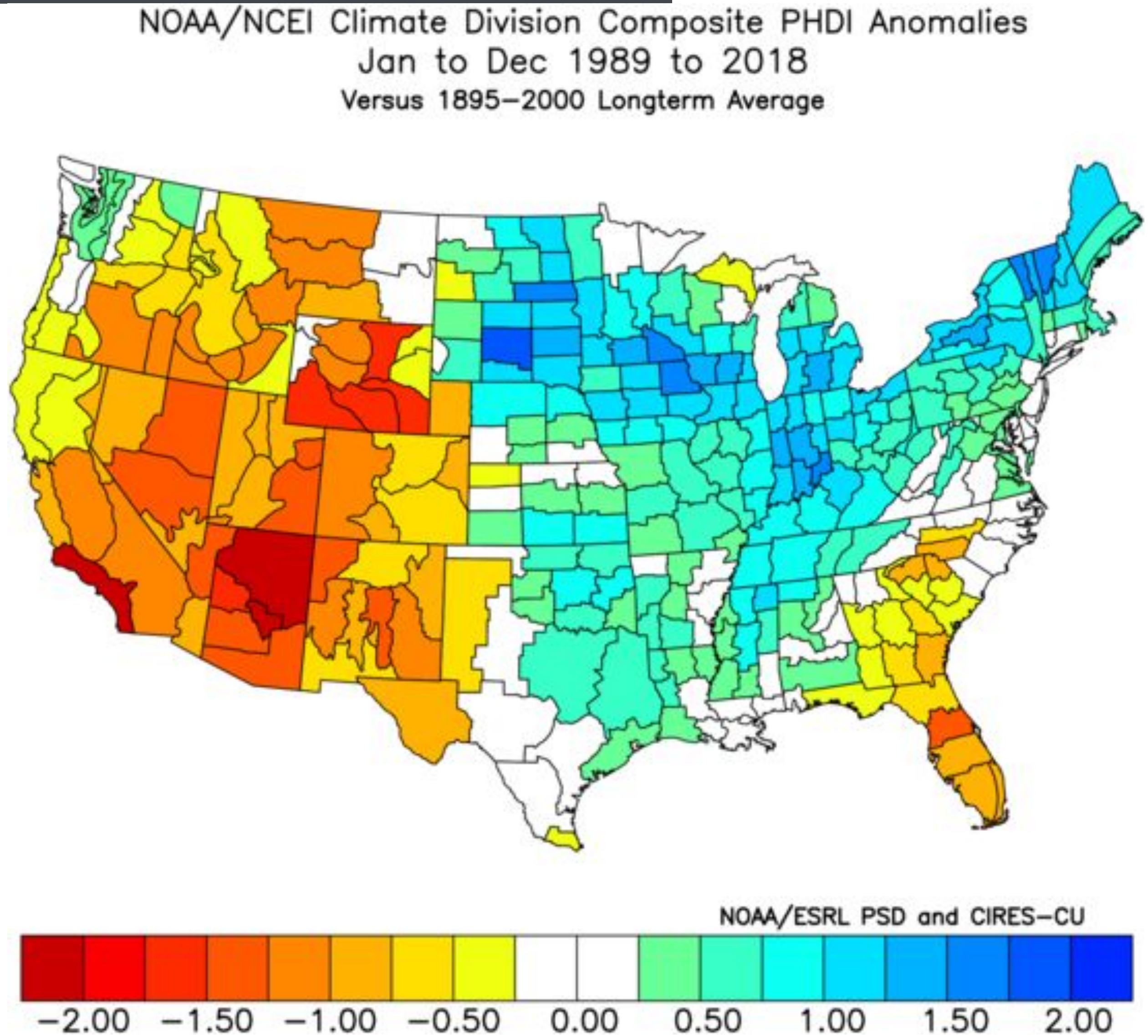


- The Ohio Basin is somewhat noisy with a small trend toward wetter conditions
- The Missouri Basin shows pronounced decadal variability.
- Part of NIDIS/ USDA/ USACE/ M.R. cities & towns initiative trade footprint study -- understand economic impact of drought on corridor (ag., commercial nav. and trans., manufacturing, rec+tourism).

Figures courtesy Andy Hoell and Marty Hoerling (NOAA ESRL)

ESRL | Physical Sciences Division

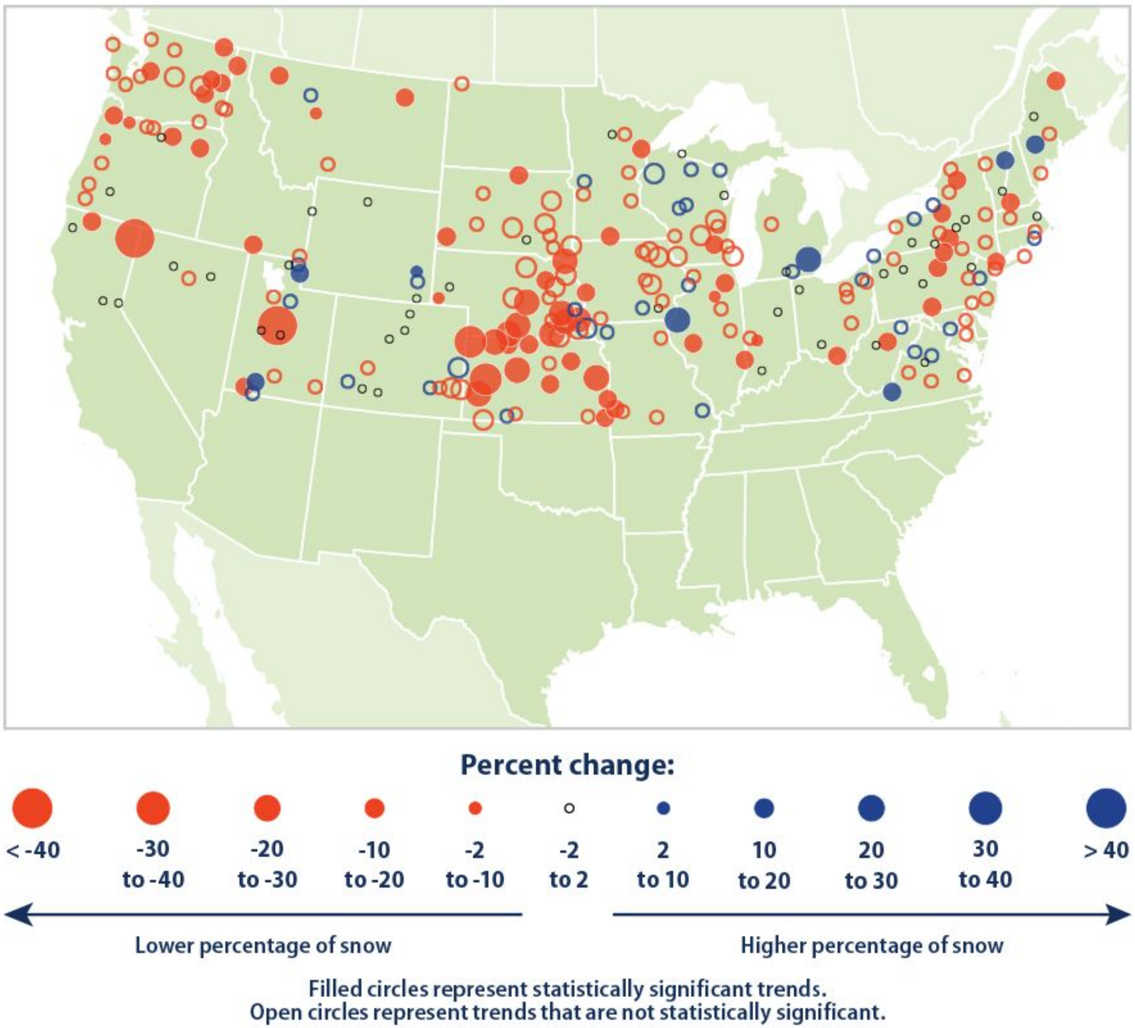
Hydrology in broad Mississippi Basin



- A plot of the integrative Palmer Hydrological Drought Index (PHDI) shows regions of wetter- and drier-than average conditions compared to the 20th century average.

Figure courtesy Andy Hoell and Marty Hoerling (NOAA ESRL)

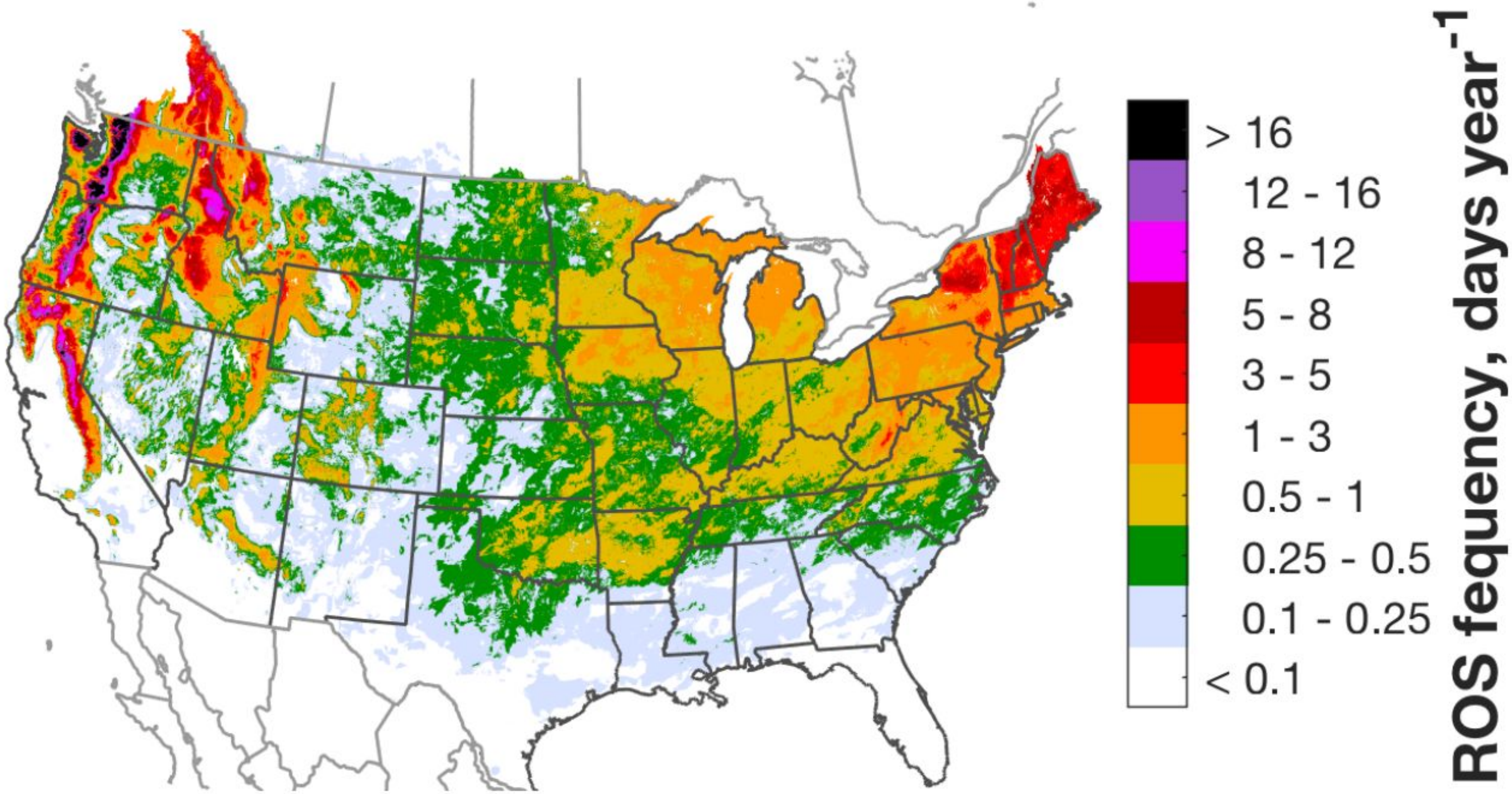
Change in Snow-to-Precipitation Ratio in the Contiguous 48 States, 1949–2016



https://www.epa.gov/climate-indicators/climate-change-indicators-snowfall

MAPP
Modeling, Analysis, Predictions, and Projections

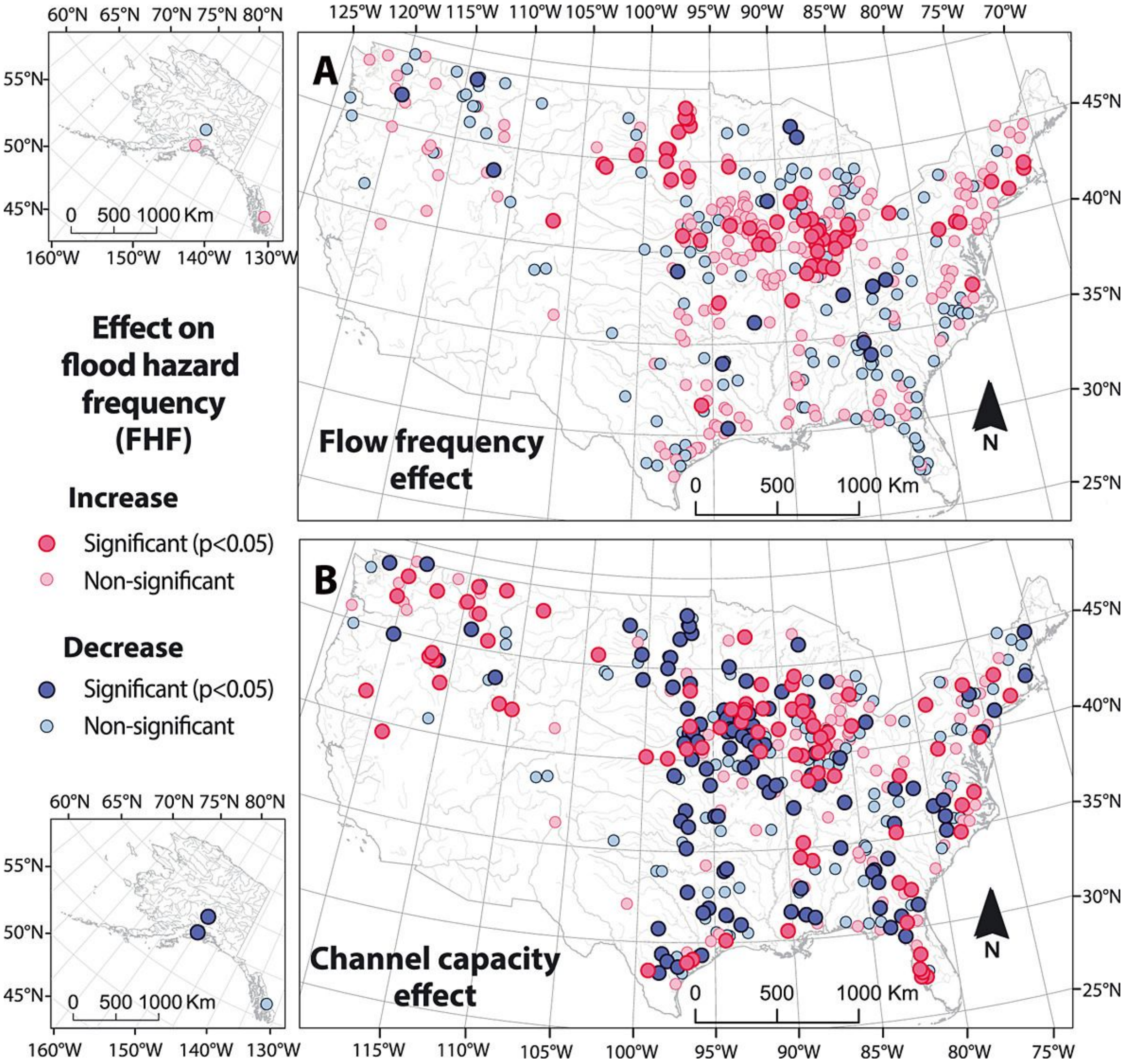
Understanding climate interactions



- Rain-on-snow events can contribute significantly to flooding in the spring season; new research is seeking to understand the interactions that lead to these events, how they are changing, and implications for the broader hydroclimate.

Figure courtesy Keith Musselman (CU Boulder)

Flood frequency change due to flow frequency vs. channel capacity changes 1950-2013



“Channel capacity effects tended to reduce flood hazard frequency in the Mississippi River Basin (through increasing channel capacity).”

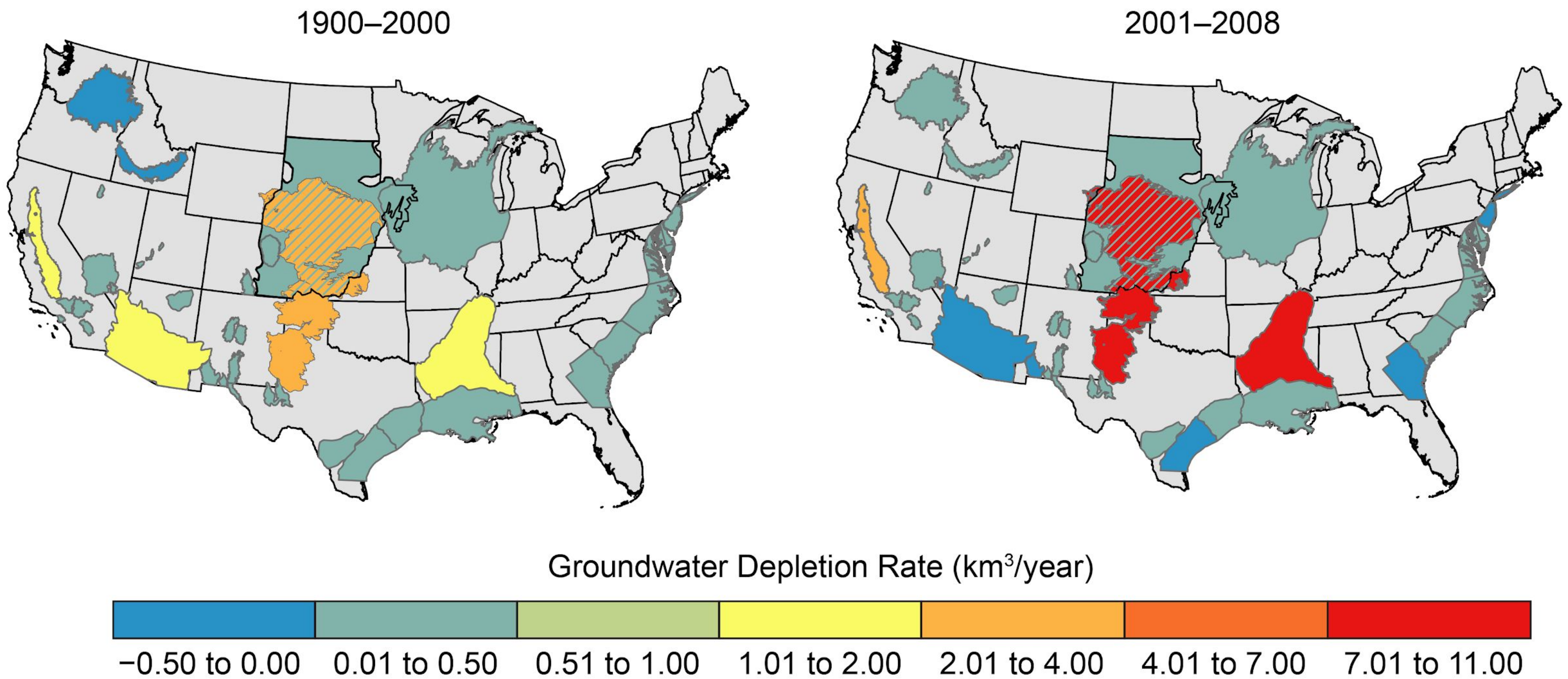
“Among our sites, increasing flow frequency trends were concentrated within the Mississippi River Basin”

Slater, L. J., M. B. Singer, and J. W. Kirchner, 2015: Hydrologic versus geomorphic drivers of trends in flood hazard. Geophysical Research Letters, 42, 370–376, doi:10.1002/2014GL062482.

Additional social/economic impacts from National Climate Assessment, Volume II (2018), Midwest, Transportation, and Water chapters:

- **Flooding** of surface streets, highways, low-lying areas
- **Drinking water contamination**, pathogen transport, impacts on well water
  - Overflows of combined sewers -> human and ecological impacts
    - Costs of adapting urban storm water systems "could exceed **$480 million/year** under either emissions scenario"
- Infrastructure impacts -- **bridge base erosion/scouring** -- costs could reach "approximately $400 million in the year 2050" under either emissions scenario
- Disruption of **barge traffic** on and **agricultural productivity** along the Mississippi
  - "Flooding on the Mississippi and Missouri Rivers in May 2011 caused an estimated $5.7 billion in damages (in 2018 dollars). One year later, drought conditions in 2012 led to record low flows on the Mississippi, disrupting river navigation and agriculture and resulting in widespread harvest failures for corn, sorghum, soybean, and other crops."
- Mold growth in flooded buildings -> **asthma/allergies**
- **Mental stress** - sleeplessness, anxiety, depression, post-traumatic stress disorder

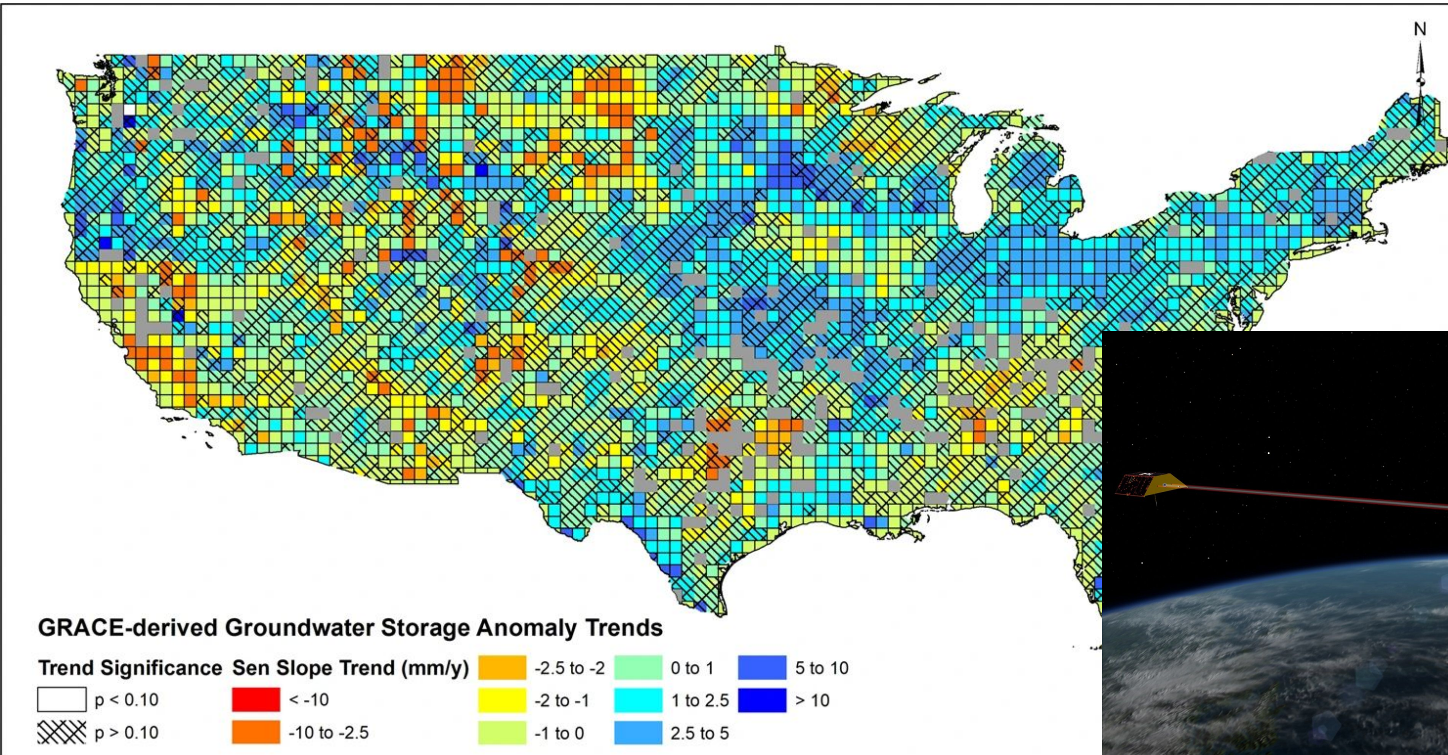
Aquifer Changes

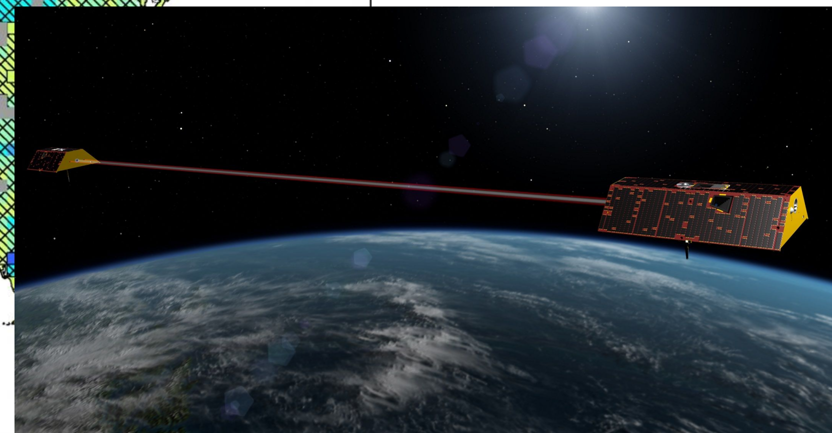


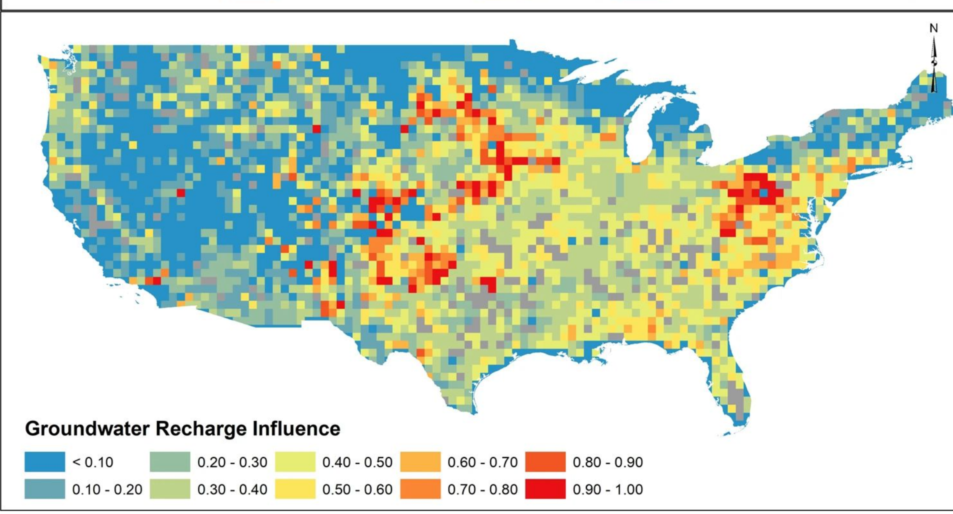
National Climate Assessment, Volume II (2018): "Groundwater supplies have been decreasing in the major regional aquifers of the United States over the last century (1900–2000). This decline has accelerated recently (2001–2008) due to persistent droughts in many regions and the lack of adequate surface water storage to meet demands."

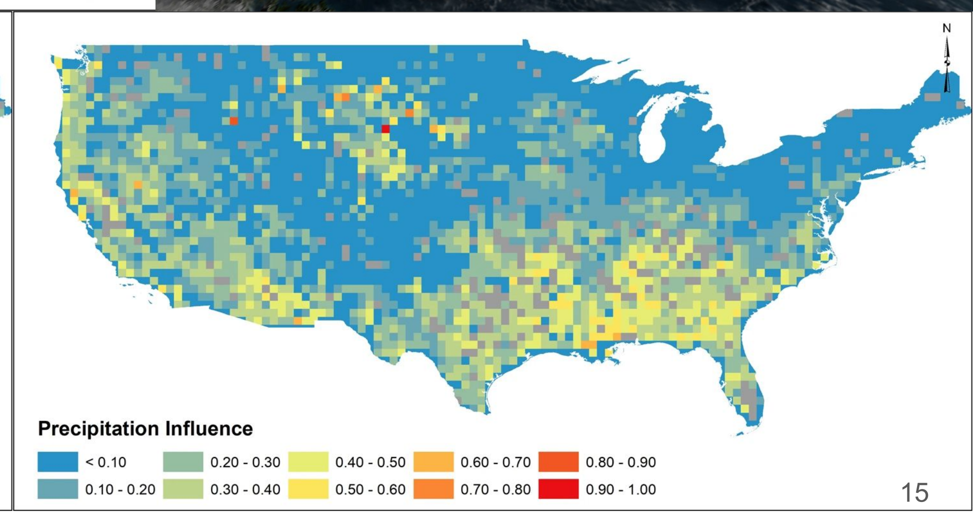
Fourth National Climate Assessment, Volume II: Figure 3.2

Aquifer Changes

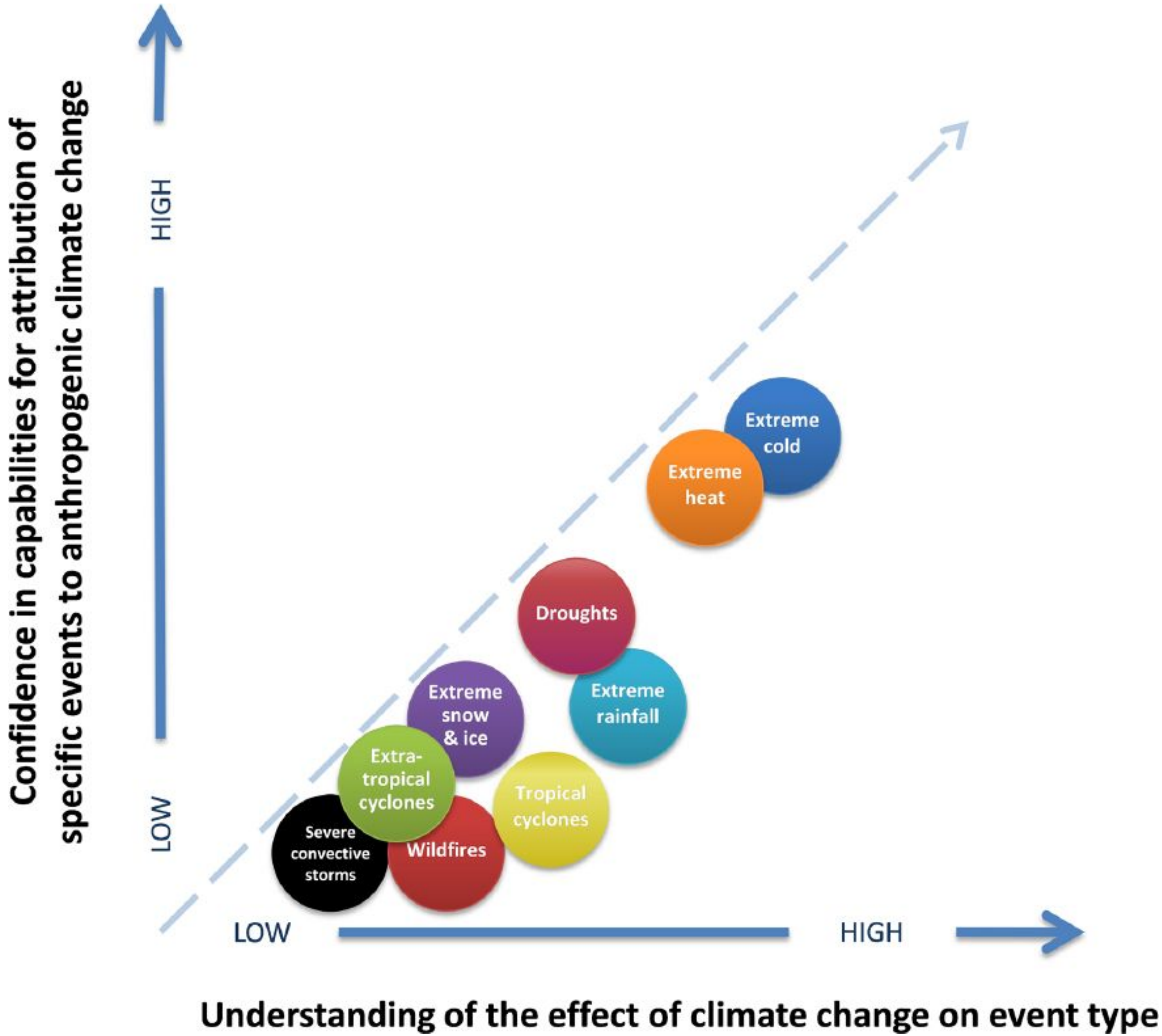








Thomas, B.F., Famiglietti, J.S. Identifying Climate-Induced Groundwater Depletion in GRACE Observations. Sci Rep 9, 4124 (2019) doi:10.1038/s41598-019-40155-y



https://www.nap.edu/read/21852/chapter/6

Fourth National Climate Assessment, Volume I, Climate Science Special Report (2017), Chapter 8

“The complex mix of processes complicates the formal attribution of observed flooding trends to anthropogenic climate change and suggests that **additional scientific rigor is needed in flood attribution studies**.”

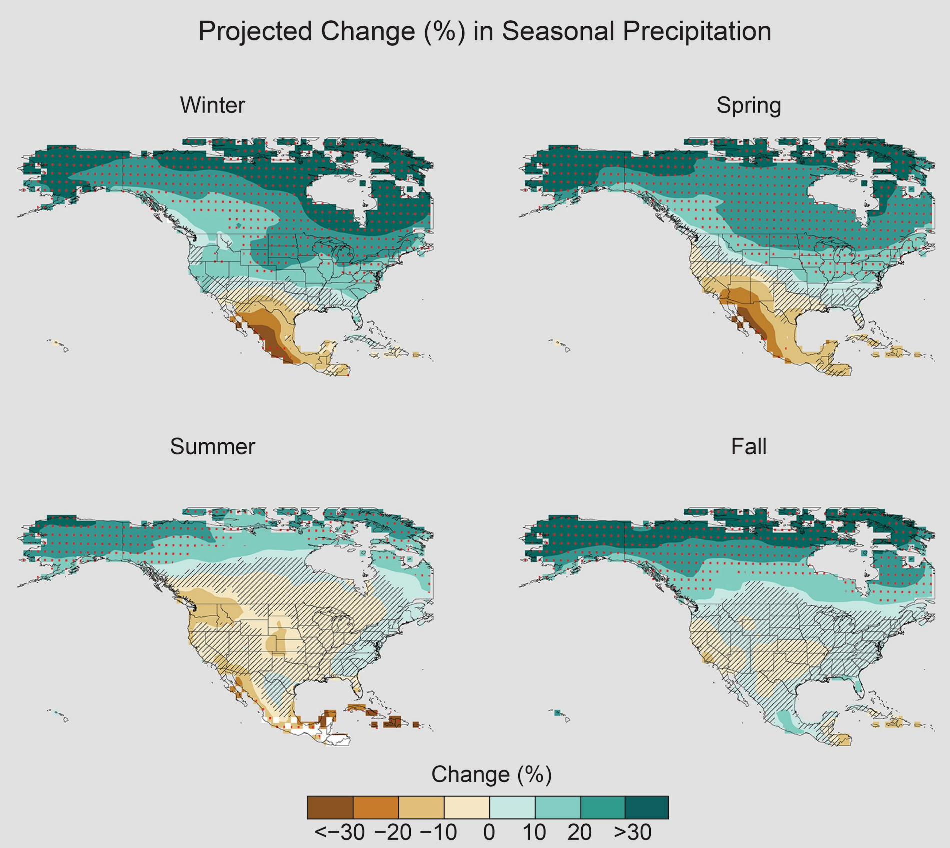
“[P]recipitation increases have been found to strongly influence changes in flood statistics. However, in U.S. regions, **no formal attribution of precipitation changes to anthropogenic forcing has been made so far**, so indirect attribution of flooding changes is not possible. Hence, no formal attribution of observed flooding changes to anthropogenic forcing has been claimed.”

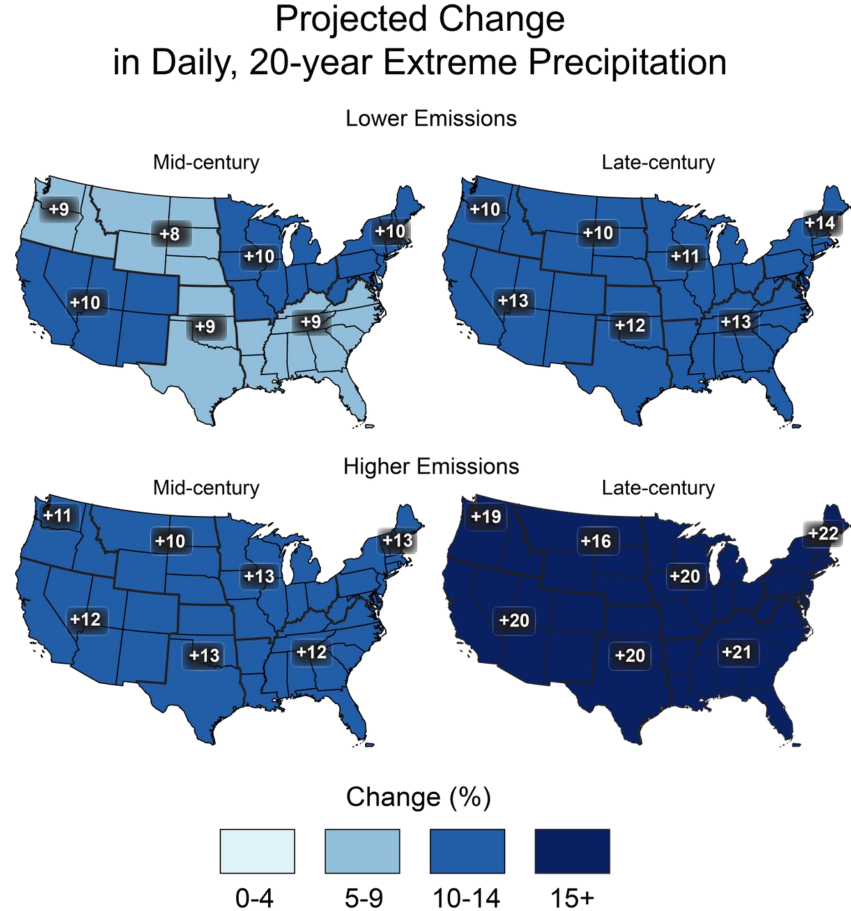
“the **Mississippi River** has undergone century-scale variability in flood frequency—perhaps linked to the moisture availability in the central United States and the temperature structure of the Atlantic Ocean.”

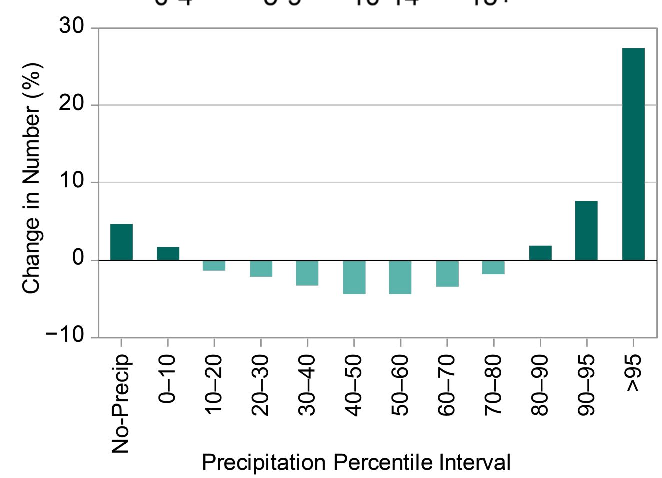
Fourth National Climate Assessment, Volume I, Climate Science Special Report (2017), Chapter 8

“We conclude that there is **medium confidence that detectable** (though not attributable to anthropogenic forcing changes) i**ncreases in flood statistics have occurred in parts of the central United States**.”

“Key Finding 3 of Chapter 7: Precipitation Change states that the frequency and intensity of heavy precipitation events are projected to continue to increase over the 21st century with high confidence. Given the connection between extreme precipitation and flooding, and the complexities of other relevant factors, we concur with the IPCC Special Report on Extremes (SREX) assessment of “**medium confidence (based on physical reasoning) that projected increases in heavy rainfall would contribute to increases in local flooding in some catchments or regions**.””



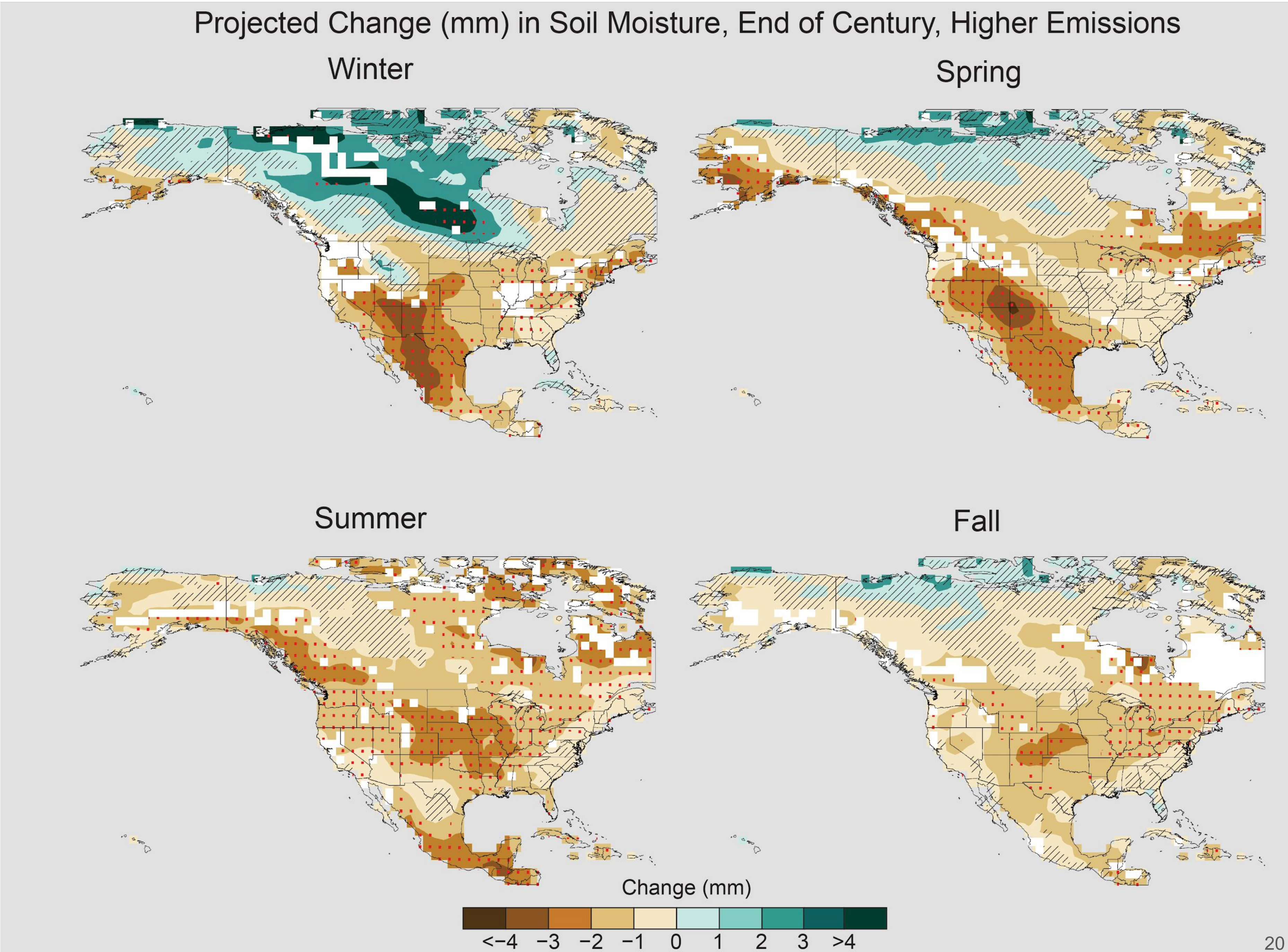




Projections of changes in seasonal precipitation (above) based on the period 2070-2099 compared to 1976-2005 for the higher emissions (RCP8.5) scenario.

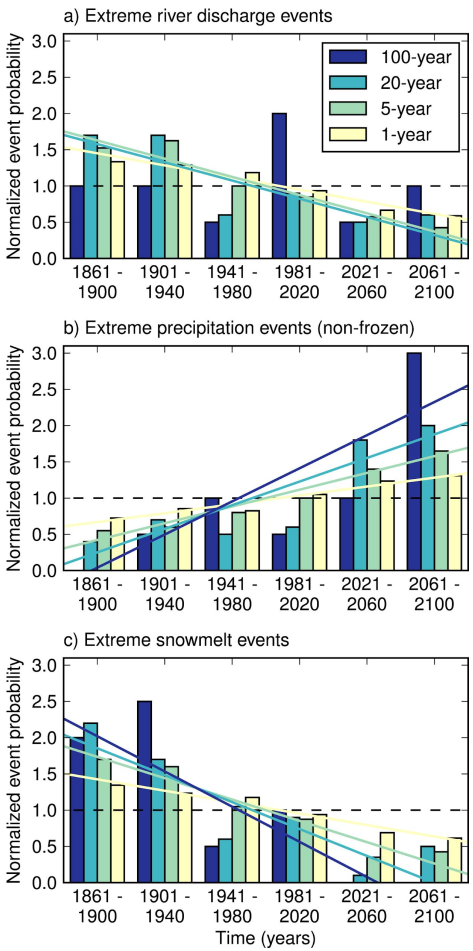
Projections of changes in the magnitude of a 1-in-20-year precipitation extreme (top right) and bins of precipitation by intensity from light to heavy (bottom right).

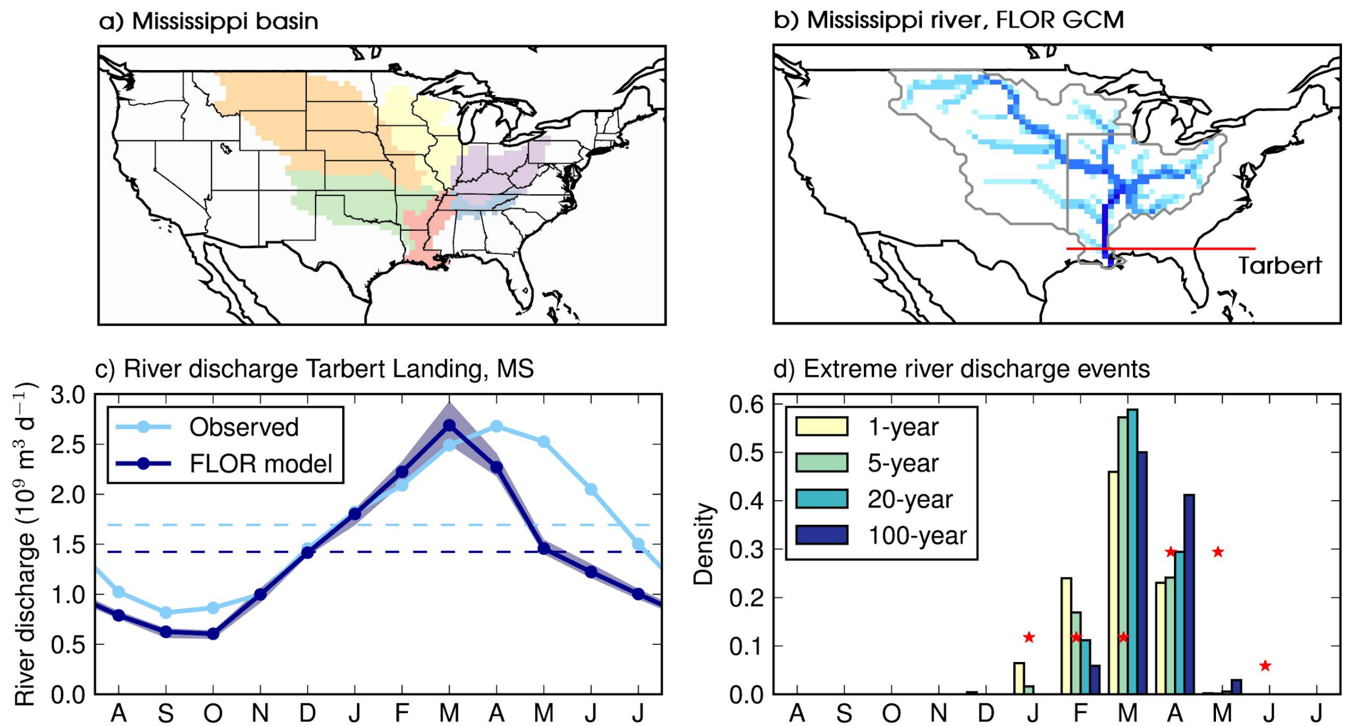
Fourth National Climate Assessment, Volume I, Climate Science Special Report: Figures 7.7 and 7.8



Fourth National Climate Assessment, Volume I, Climate Science Special Report: Figures 8.1

Modeling the Mississippi Basin in a Global Climate Model





- A 50-km climate model, developed by NOAA GFDL, was used to simulate extremes in the Mississippi Basin.
- The model projects significant increases in extreme precipitation and significant decreases in discharge events, attributed to decreases in snowpack and snowmelt.

van der Wiel, K., S.B. Kapnick, G.A. Vecchi, J.A. Smith, P.C. Milly, and L. Jia, 2018: 100-Year Lower Mississippi Floods in a Global Climate Model: Characteristics and Future Changes. J. Hydrometeor., 19, 1547–1563, https://doi.org/10.1175/JHM-D-18-0018.1

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