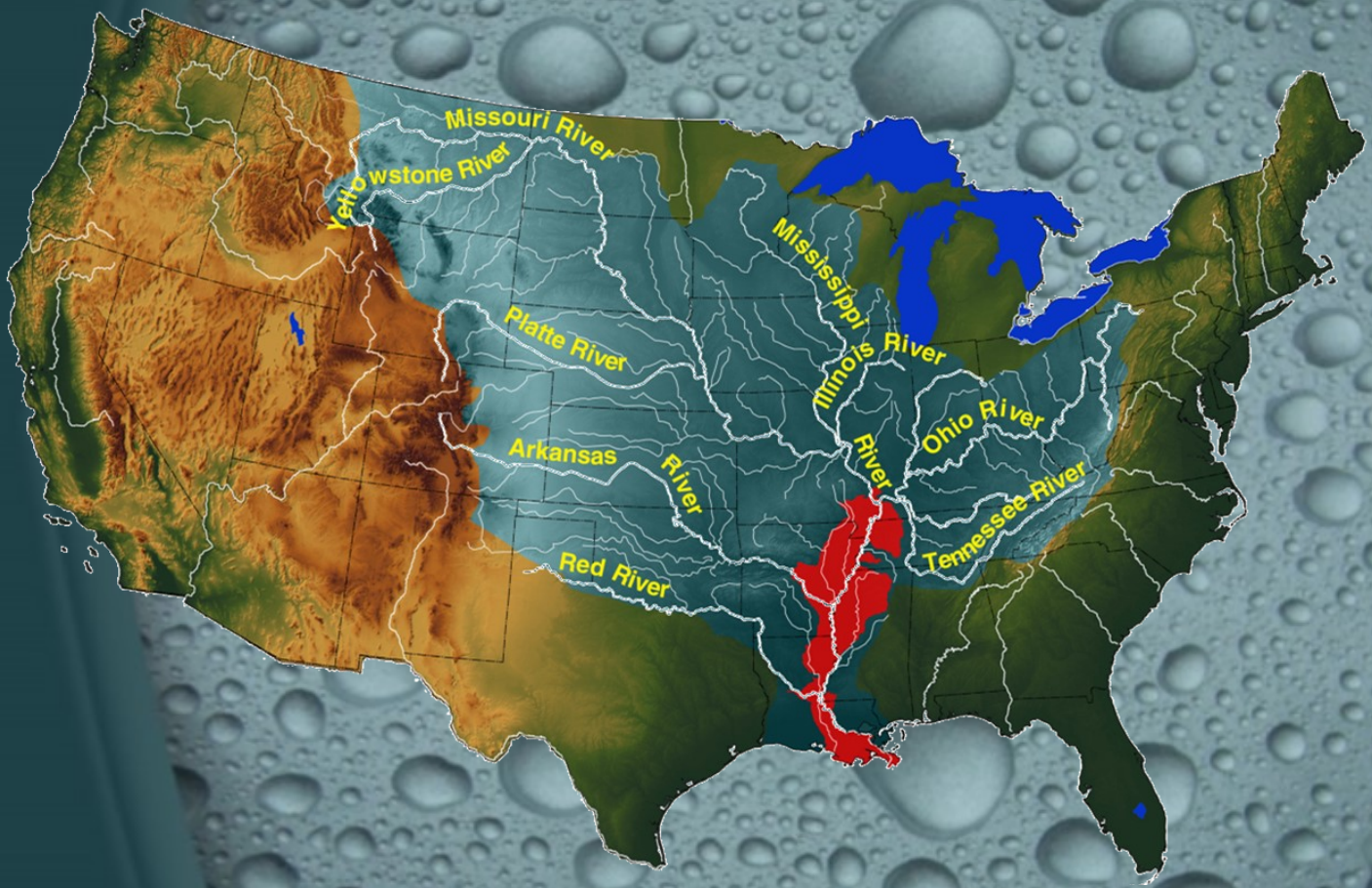
Precipitation Trends in the Mississippi River Watershed



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Flooding along the Mississippi River has increased both in frequency and magnitude during the past three to five decades. During the 49-year period of 1970 to 2018, stages at Cairo, Illinois - the confluence of the Mississippi and Ohio rivers - have exceeded major flood stage of 52.0 feet 16 times, as opposed to 13 times during the 72-year period of 1898 to1969.

The 2002 U.S. Department of State Climate Action Report stated that total annual precipitation has been increasing, not only across the United States but worldwide, over the past 100 years. In his 2009 paper, *Global Climate Change Impacts in the United States*, Thomas R. Karl concludes that total annual precipitation for the contiguous United States has increased an average of about 5 percent over the past 50 years when compared to the 1901-2012 average. Walsh et al. (2014) quantifies the increase as 4 percent nationally during the period of 1901 to 2015. Basically, precipitation is increasing nationally **(Figure 1)**.

The Midwestern and New England states have shown the greatest increase in annual precipitation during the past 50 years **(Figure 1)**. When dealing with flooding in the Mississippi Valley, annual increases may not be the best benchmark since the majority of flooding occurs during the spring.

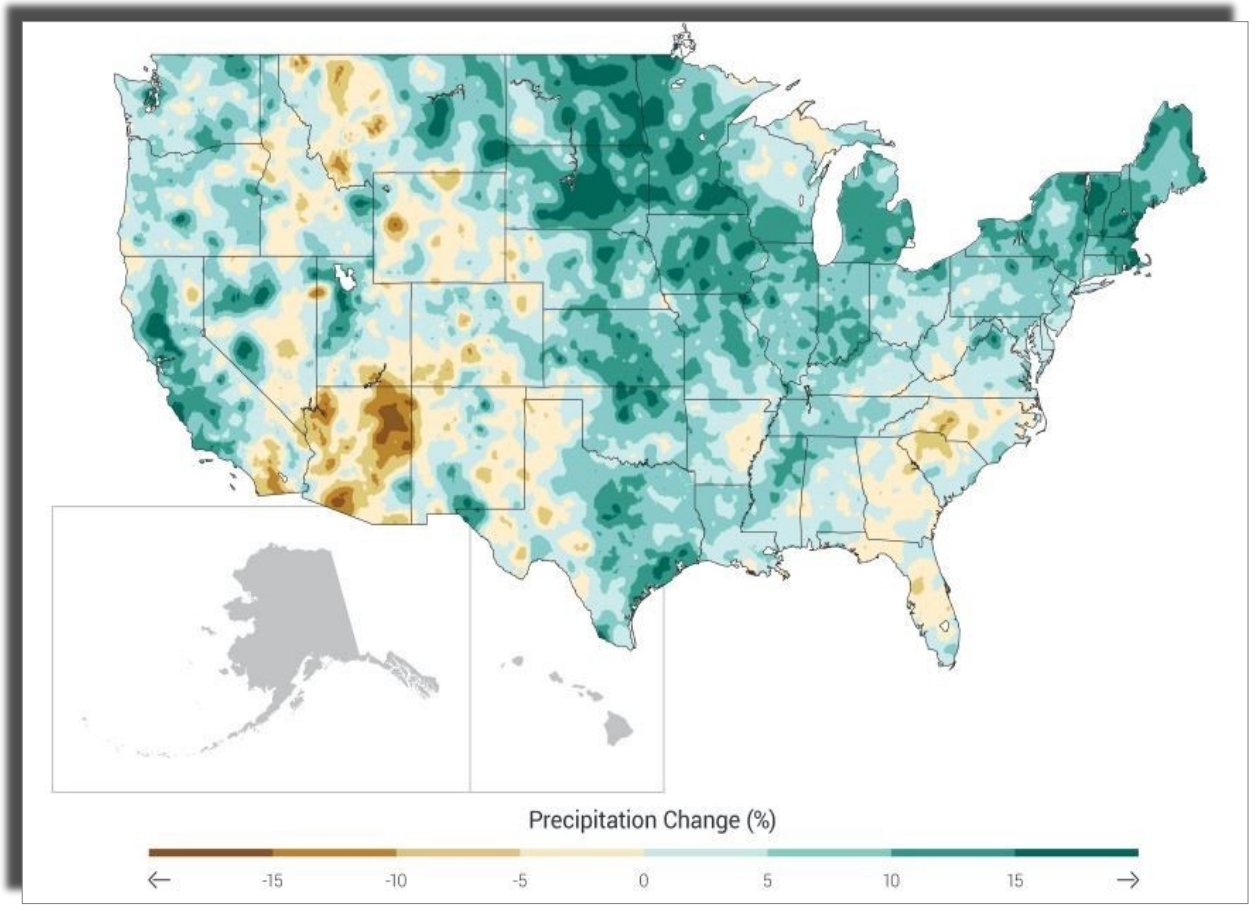


FIGURE 1. Increase in annual precipitation for the period 1966-2015 as compared to the 1901-2015 average.

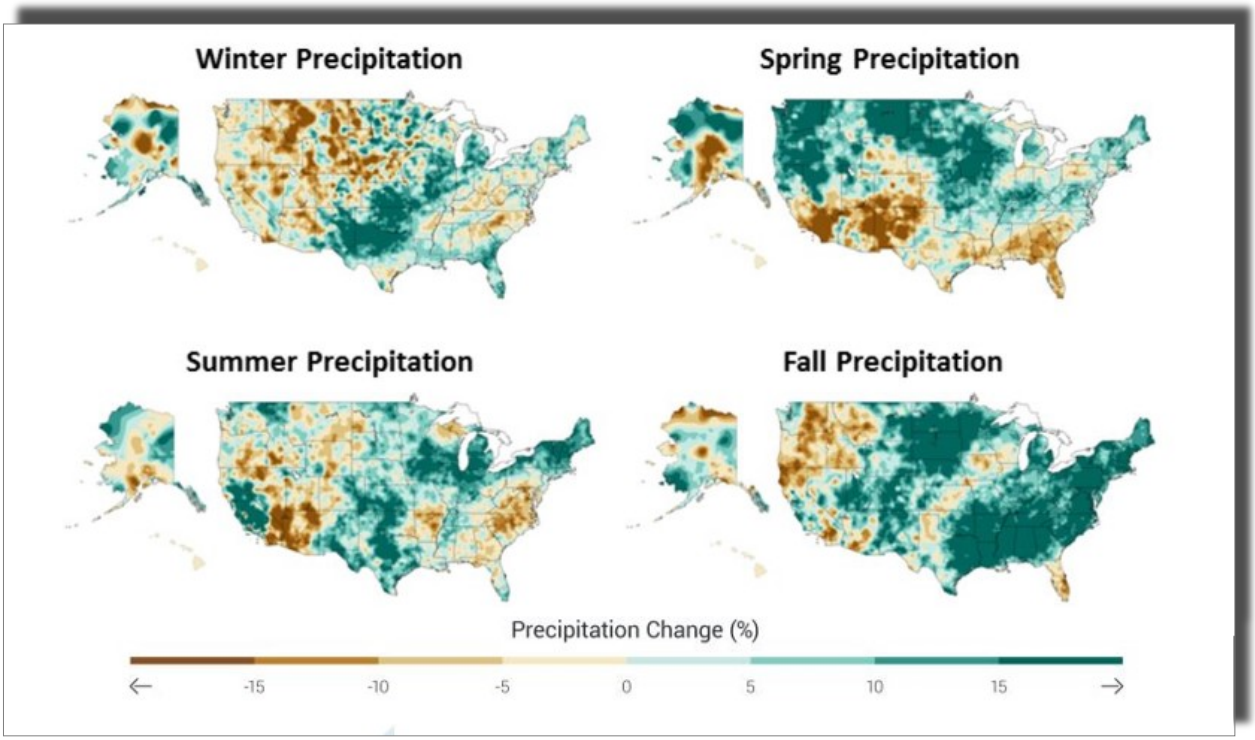


FIGURE 2. Seasonal changes in precipitation for the period 1966-2015 as compared with the 1901-2015 averages.

Although winter precipitation is about the same over the Mississippi watershed, spring precipitation is markedly higher over the Ohio, Missouri and Mississippi watersheds, upstream from the confluence of the Mississippi and Ohio rivers **(Figure 2)**. The greatest increases in seasonal precipitation have occurred over the Arkansas/Red/lower Mississippi valleys and over Minnesota and the Missouri Valley during the fall **(Figure 2)**. It is vitally important to recognize that the northern, increased precipitation during the fall generally reflects the moister soil going into the winter freeze, allowing for more water to be available for spring melt.

Local studies have quantified the percentages by basin over the Mississippi watershed.

2015-2016 winter flood: Railroad bridge under water in Valley Park, Missouri

Valley Park, Missouri, during 2015-2016 winter flood

Table 1 reflects the percentage of increase in precipitation during the 30 -year period of 1982-2011, as compared with the 1901-2011 averages over the Mississippi watershed's various basins. Data, compiled from the National Climate Data Center in Asheville, North Carolina, reflects each basins weighted average of all climate divisions upstream from the basin.

2011 flood: A community protected by a Mississippi River levee

BASIN	DEC-FEB	MAR-MAY	JUN-AUG	SEP-NOV	ANNUAL
Upper Mississippi River at Grafton, IL	+6.9	+6.3	+5.4	+8.2	+6.6
Missouri River at Hermann, MO	-1.1	+6.6	+1.8	+7.8	+4.2
Mississippi River at St. Louis, MO	+2.0	+6.5	+3.0	+8.0	+5.0
Ohio River at Metropolis, OH	+0.2	+3.8	+2.2	+11.4	+4.3
Cairo, IL (confluence of Miss. & Ohio rivers)	+0.9	+5.0	+1.8	+8.7	+4.2
Arkansas River at Little Rock, AR	+11.3	+4.4	+2.5	+8.3	+5.8
Red River at Alexandria, LA	+5.9	-3.8	+3.6	+9.7	+3.7
Entire Mississippi River Watershed	+3.1	+3.0	+2.0	+9.2	+4.3

TABLE 1. Seasonal changes in precipitation for 1982-2011, as compared to 1902-2011 over the various basins that comprise the Mississippi watershed.

2013 flooding on the upper Mississippi River

Weighted averages were calculated by basin for the 30-year running average over the watershed upstream from the confluence of the Mississippi and Ohio rivers at Cairo, Illinois **(Figure 3)**.

It is noted that annual precipitation values have steadily increased since the 1970s. The difference is 7.8 percent when comparing the 1982-2011 period with the 1932-1961 timeframe, and 8.4 percent when comparing the 26-year average from 1992-2017 with the same 1932-1961 period. Increases in seasonal and annual precipitation over the Mississippi watershed are not the only reason for the increase in flooding that has occurred during the past several decades. Heavy rains from extreme rainfall events also increased dramatically during the 1992-2017 time period.

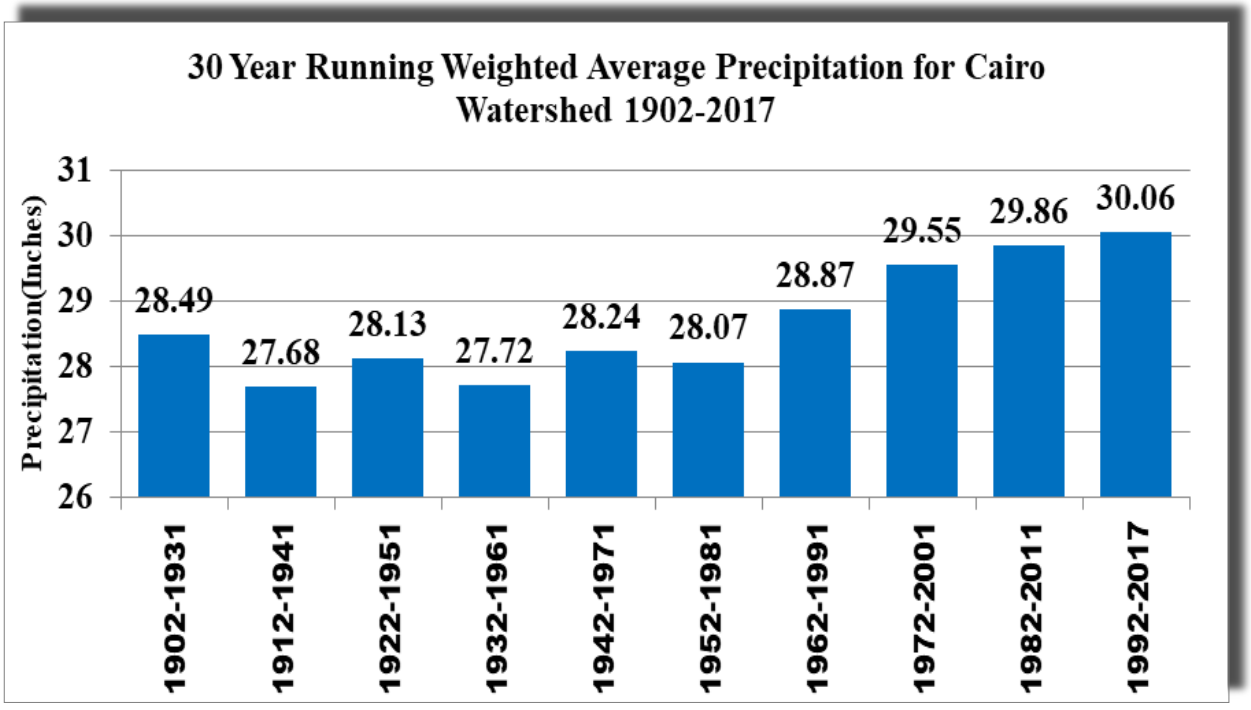


FIGURE 3. 30-year running weighted average of precipitation over the watershed upstream from Cairo, Illinois.

According to the 2014 National Climate Assessment, "Heavy downpours are increasing nationally, especially over the last three to five decades. The heaviest rainfall events have become heavier and more frequent, and the amount of rain falling on the heaviest rain days has also increased. Since 1991, the amount of rain falling in very heavy precipitation events has been significantly above average. This increase has been greatest in the Northeast, Midwest and Upper Plains – more than 30 percent above the 1901-1960 average. There has also been an increase in flooding events in the Midwest and Northeast, where the largest increases in heavy rain amounts have occurred." **Figure 4** denotes decadal trends in heavy precipitation during the 112-year period from 1900 to 2012.

2016 flooding in Cedar Rapids, Iowa

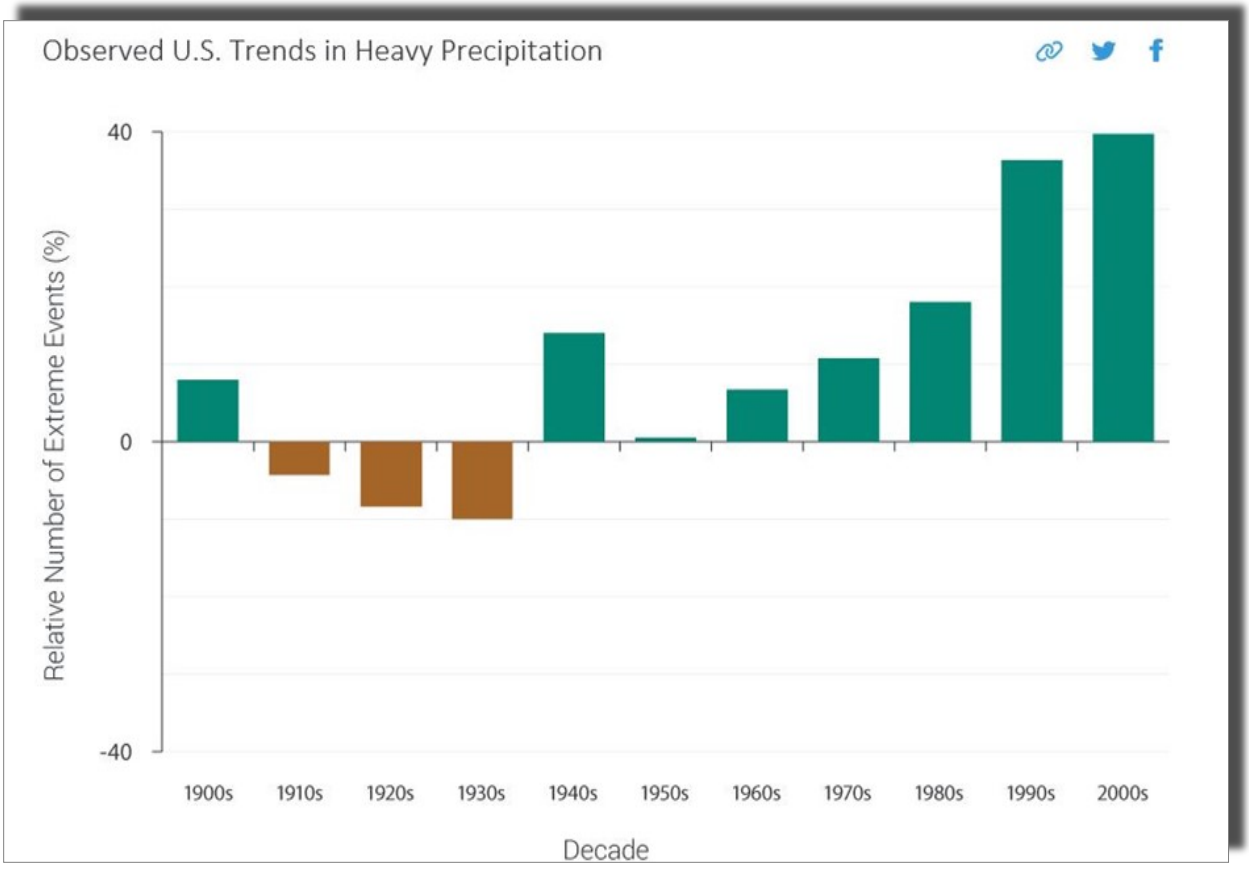


FIGURE 4. Kunkel, K. E. et al., 2013: Monitoring and understanding trends in extreme storms: State of knowledge. Bulletin of the American Meteorological Society, 94, doi:10.1175/BAMS-D-11-00262.1.

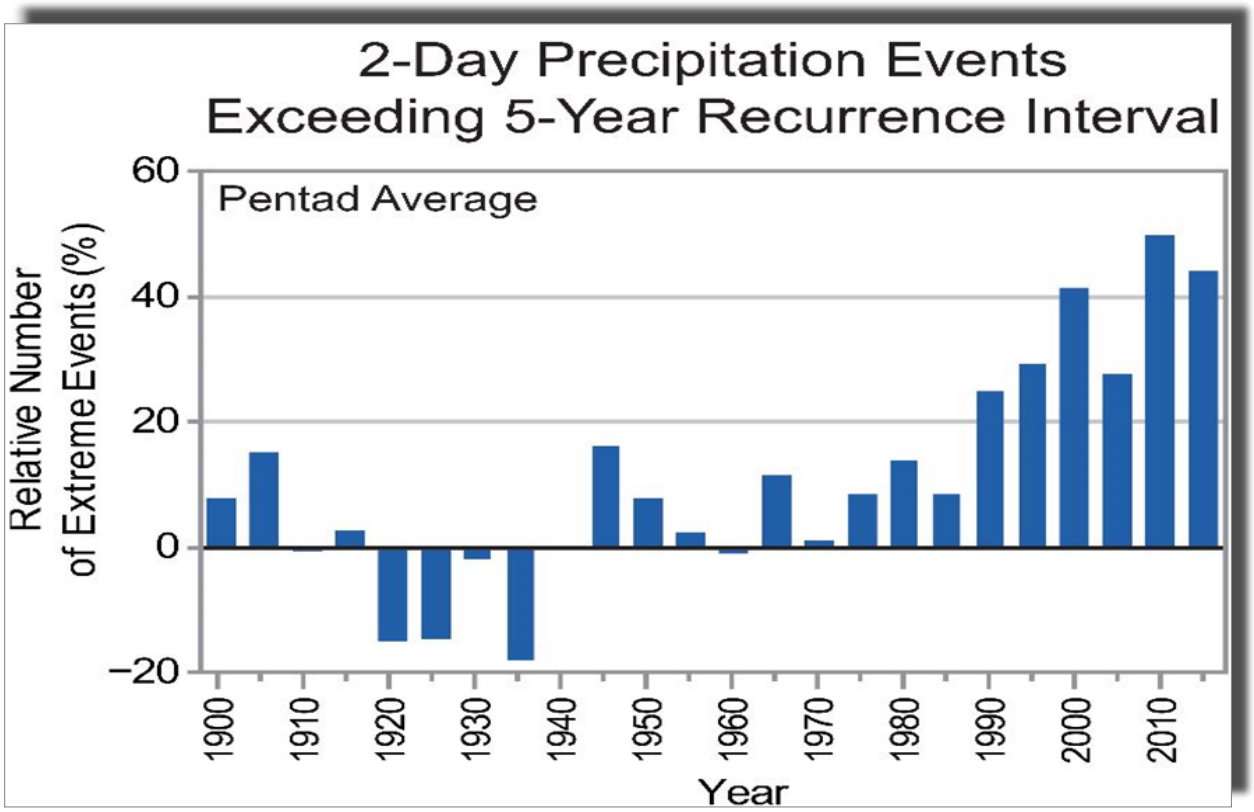
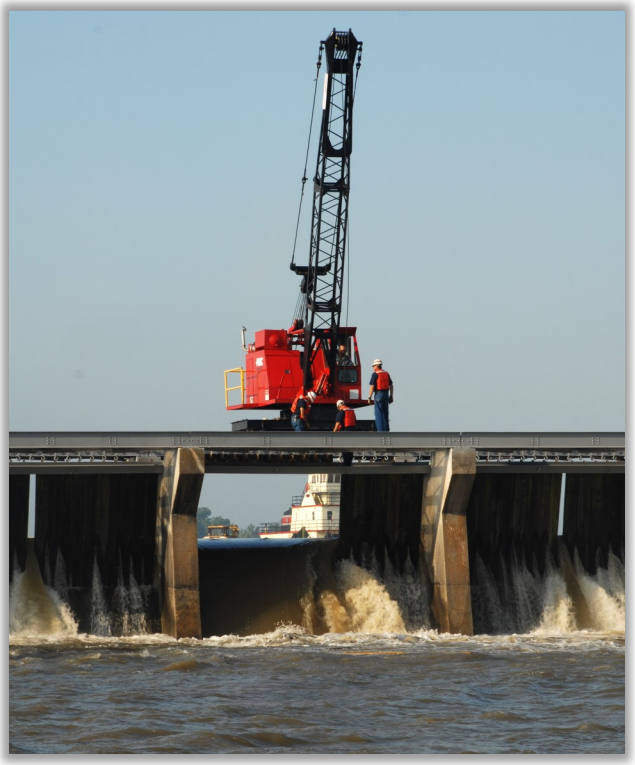


FIGURE 5. Index of the number of two-day precipitation events exceeding the station-specific threshold for a five-year occurrence interval in the contiguous U.S.

According to the article *Monitoring and Understanding Trends in Extreme Storms* (Kunkel, et al 2013), "There is strong evidence for a nationally averaged upward trend in the frequency and intensity of extreme precipitation events. The COOP (Cooperative Observer) network is considered adequate to detect such trends. The causes of the observed trends have not been determined with certainty, although there is evidence that increasing atmospheric water vapor may be one factor." **Figure 5** shows a significant increase in two-day rainfall events that have exceeded the five-year recurrence interval over the contiguous U.S. since the 1990s.



2011 flood: Raising needles at the Bonnet Carré Spillway

Karl et al. (2009) breaks down the percentages of increase in precipitation that has fallen in very heavy rain events from 1958 to 2012 by region as compared to the 100-year average (**Figure 6**). A marked 37 percent increase in rain that has fallen during very heavy rain events is noted over the Midwestern states.

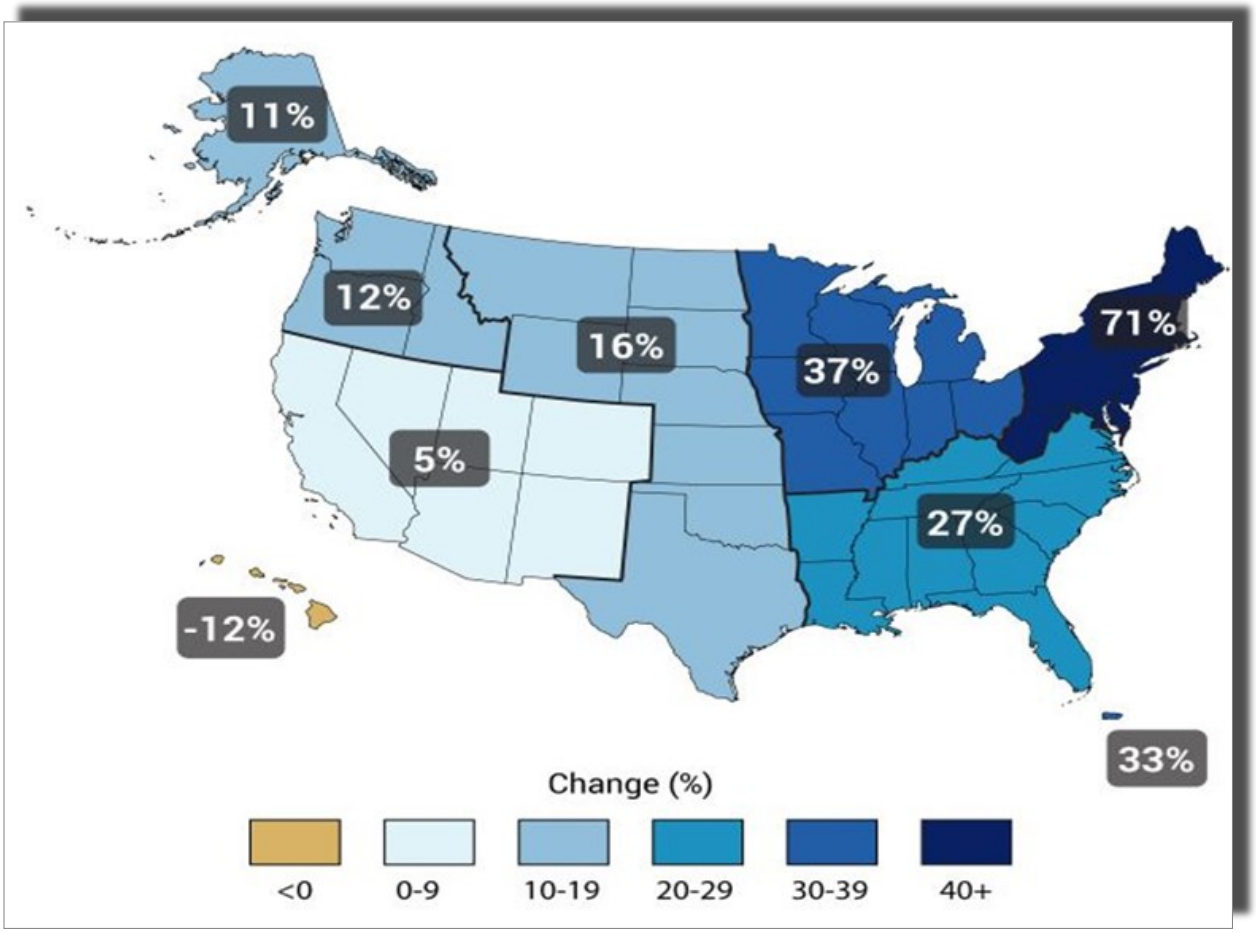


FIGURE 6. Percentage of increase in the amount of precipitation falling in very heavy rain events by region.

2015-2016 flood: Flooding in the St. Louis District's area of operation

Flood water and debris at Lock and Dam 20 on the Mississippi River in Canton, Missouri, 2014

So, how has the Mississippi River responded to the increase in precipitation? **Figure 7** depicts the percentage of years that Cairo (at the confluence of the Ohio and Mississippi rivers) has exceeded the National Weather Service's (NWS) minor/moderate/major flood stage per 30-year period. It is noted that there is minimal difference in the percentage (83-97 percent) of minor flood stage occurrences during the 30-year periods.

When comparing moderate flood stages, after a 47 percent and 50 percent probability during the first two periods, the remainder of the periods were also fairly uniform ranging from 60-73 percent. The greatest percentage difference has occurred in the major flood stage category. While the first seven 30-year periods ranged from 13-20-percent occurrences, the last three 30-year periods have risen to about double that, with 30-38 percent of the years from 1972 to 2017 exceeding the NWS major flood stage of 53 feet at Cairo.

2011 flood: Near the Birds Point-New Madrid Floodway, in southeast Missouri just below the confluence of the Ohio and Mississippi rivers

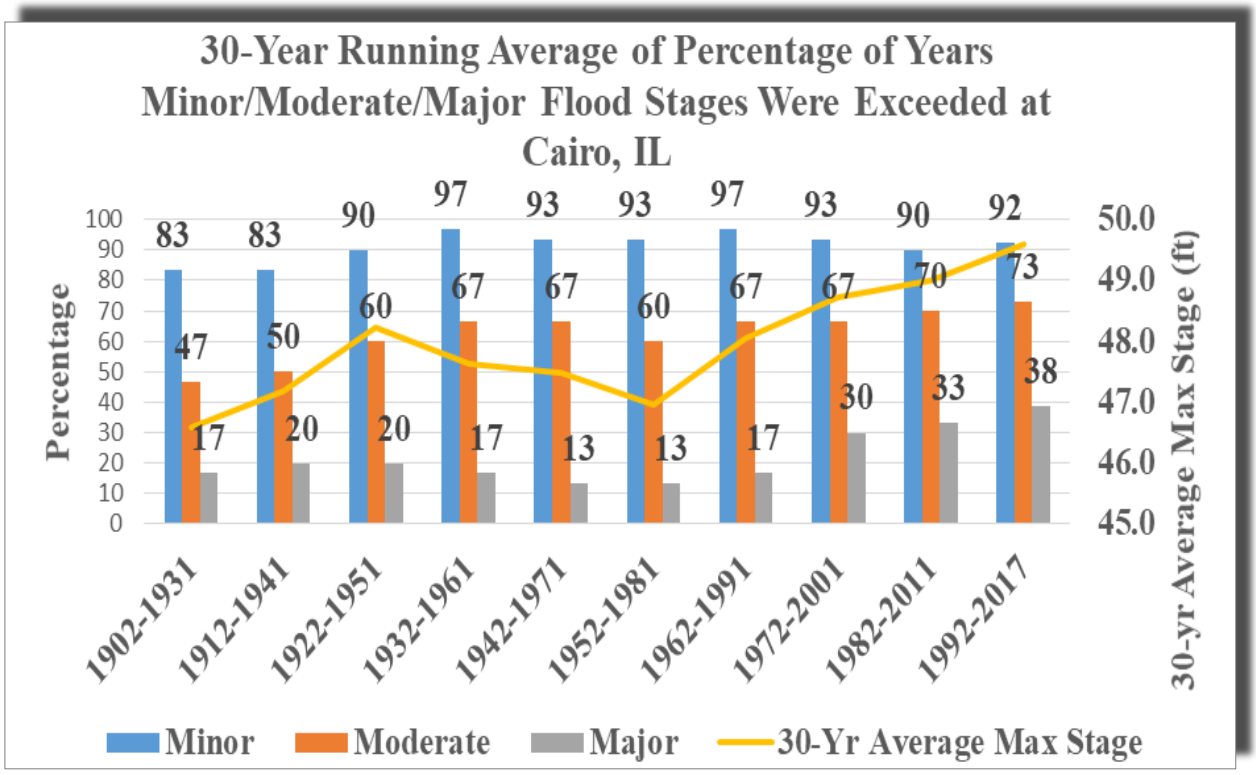
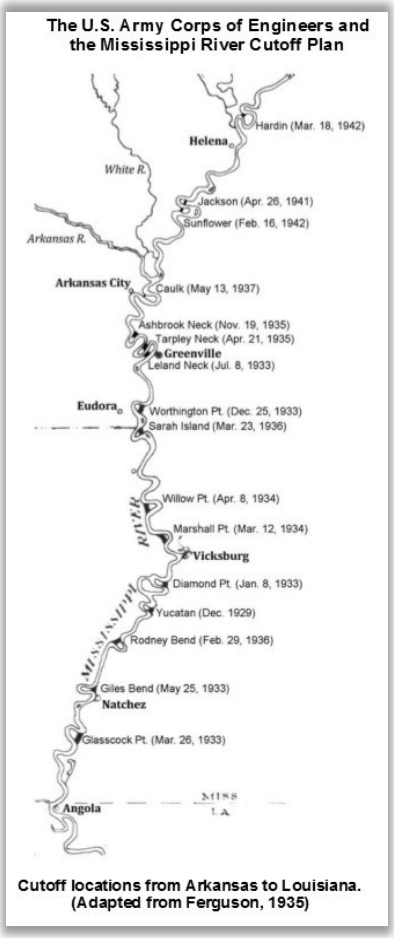


FIGURE 7. Percentage of years exceeding the NWS minor/moderate/major flood stages per 30-year period at Cairo.

This rise in percentages coincides with both the increases in precipitation trends and the frequency of very heavy rain events discussed earlier. It should also be noted that the 30-year average of maximum annual stages (represented by the yellow line in **Figure 7**) has increased from approximately minor flood stage during the 1952-1981 time period to above moderate flood stage during the 1992-2017 period.

Proceeding farther downstream to Arkansas City, Arkansas, at the confluence of the Arkansas and Mississippi rivers, an interesting trend occurs. Although there is a corresponding increase in precipitation (**Figure 8**) and very heavy rain events as at Cairo, flood occurrences have diminished dramatically since the 1940s (**Figure 9**). This corresponds with the river cut-off program that began in the 1940s which was completed in the 1960s along the Mississippi River from Memphis, Tennessee, to near Natchez, Mississippi. Although there was a significant decrease in the past, recent changes are showing aggradation and slightly higher stages in this area.



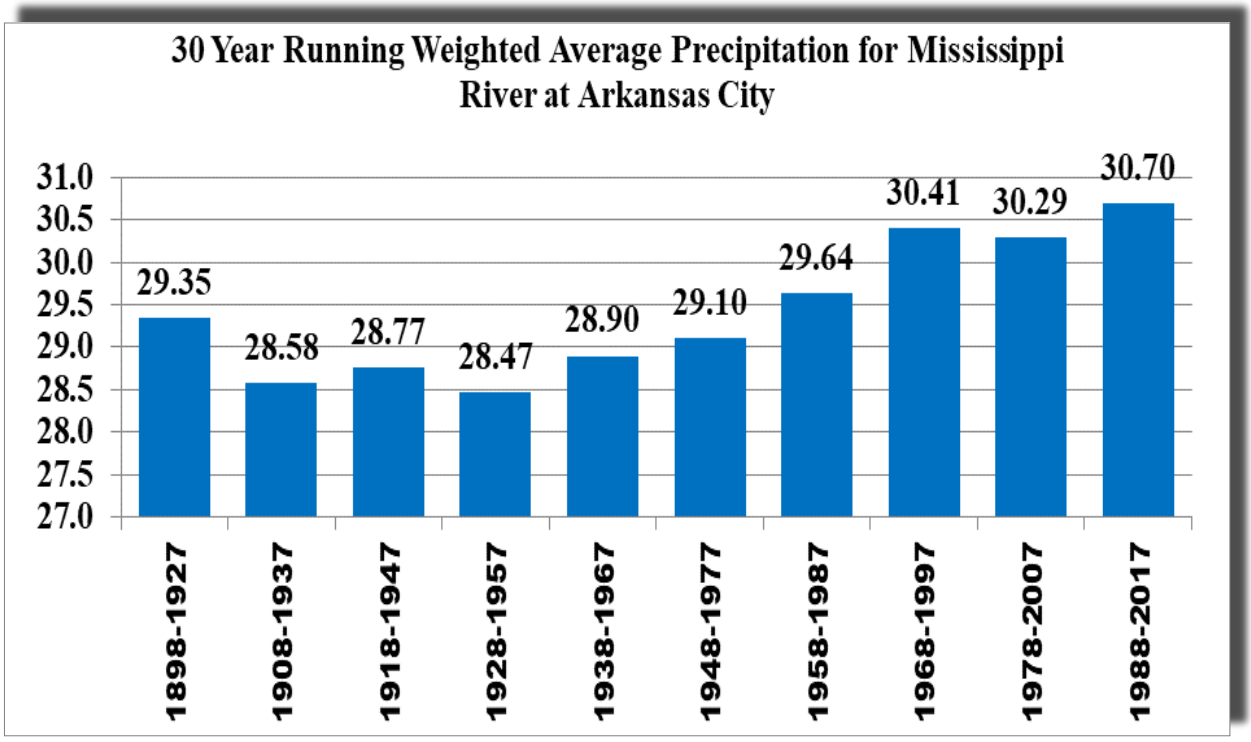


FIGURE 8. 30-year running weighted average precipitation for the Mississippi watershed at Arkansas City, Arkansas.

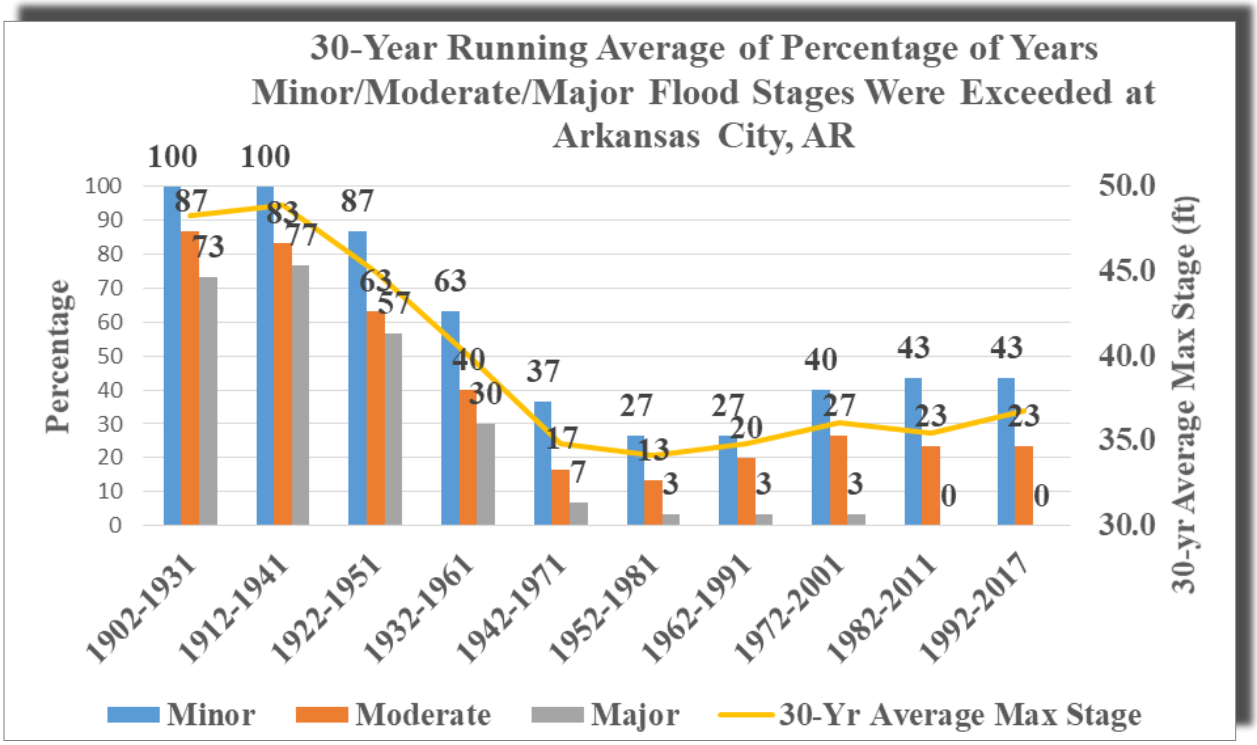


Figure 9. Percentage of years exceeding the National Weather Service's minor/moderate/major flood stage per 30-year period at Arkansas City, Arkansas.

Continuing downstream to Red River Landing, Louisiana, at the confluence of the Mississippi River and Red River, the steady increase in precipitation is noted once again (**Figure 10**).

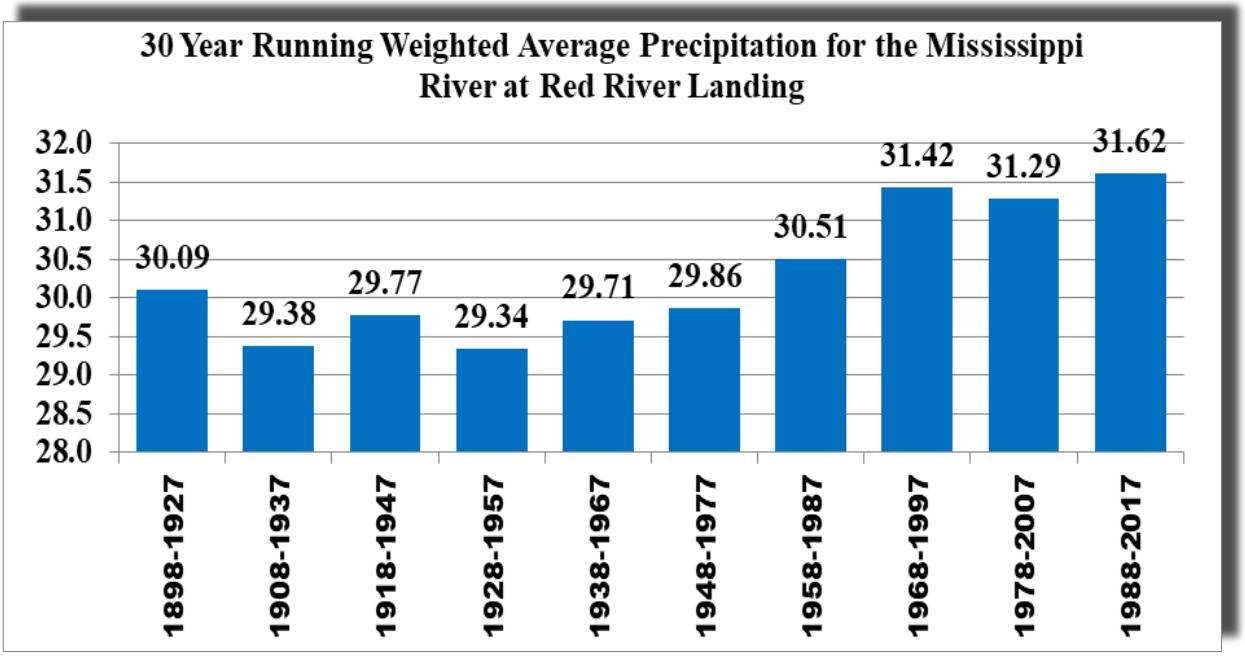


FIGURE 10. 30 year running weighted average precipitation at Red River Landing, Louisiana.

A similar trend to that at Cairo, Illinois, is noted at Red River Landing, with an increase in 30-year average moderate flood stages during the last three periods. It should be noted that the NWS major flood stage of 64 feet has never been exceeded at Red River Landing due to the construction and operation of the Morganza Floodway (**Figure 11)**.

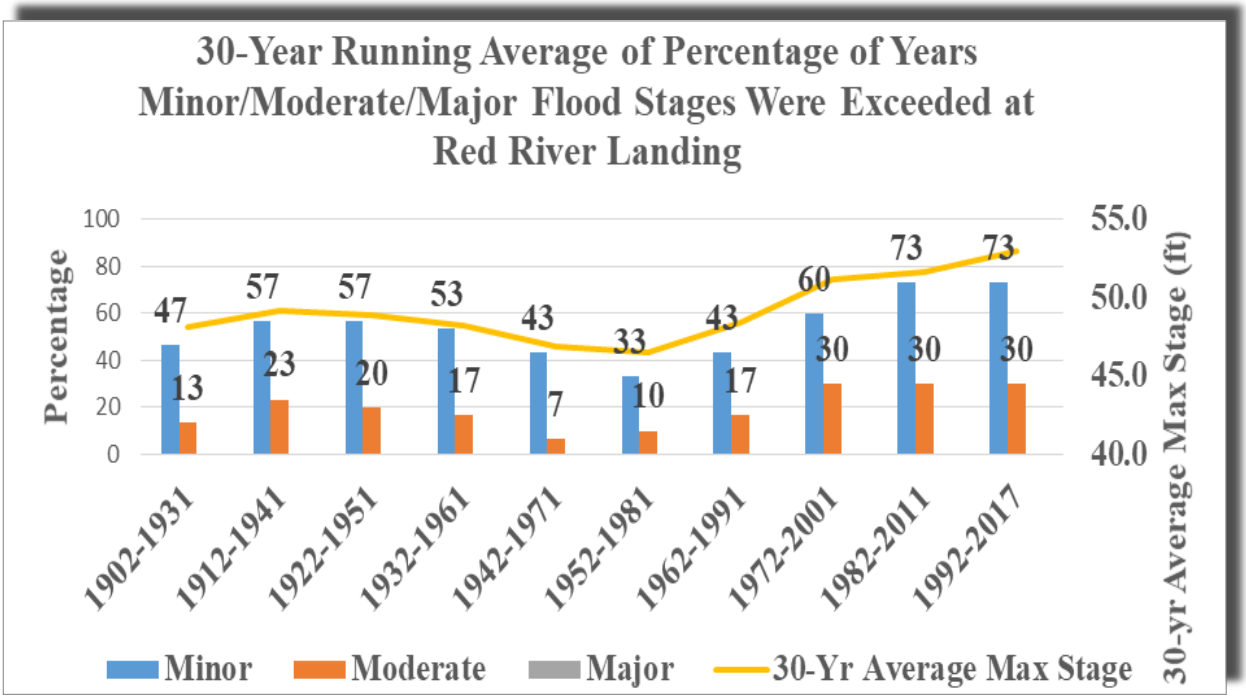


FIGURE 11. Percentage of years exceeding NWS minor/moderate/major flood stages at Red River Landing, Louisiana

Operation of Morganza Floodway during the 2011 flood

One final note, since maintaining a 9-foot navigation channel is a prime function of the Mississippi River and Tributaries (MR&T) project, **Figure 12** denotes the changes in percentages of the lowest level of the year dropping below 10 feet, 8 feet and 6.5 feet. The 6.5-feet level is the critical navigation stage at Cairo, Illinois.

It is noted that since the 1942-1971 time period, the percentage of years when the stage failed to exceed the critical navigation stage has dropped steadily. Prior to 1942, 27-43 percent of the years dropped below 6.5 feet; and after 1942, 3-10 percent of the years dropped below 6.5 feet, which coincides with the completion of the reservoirs upstream from Cairo, Illinois.

In conclusion, an increase in annual precipitation and a marked increase in spring precipitation have occurred during the past three to five decades. Also, there has been a 37 percent increase in precipitation falling in very heavy rain events over the Midwest during the past few decades. Therefore, the frequency and the magnitude of floods have increased due to more rain and a significant increase in the frequency of very heavy rainfall events.

2011 flood: Sand boil at Cairo, Illinois

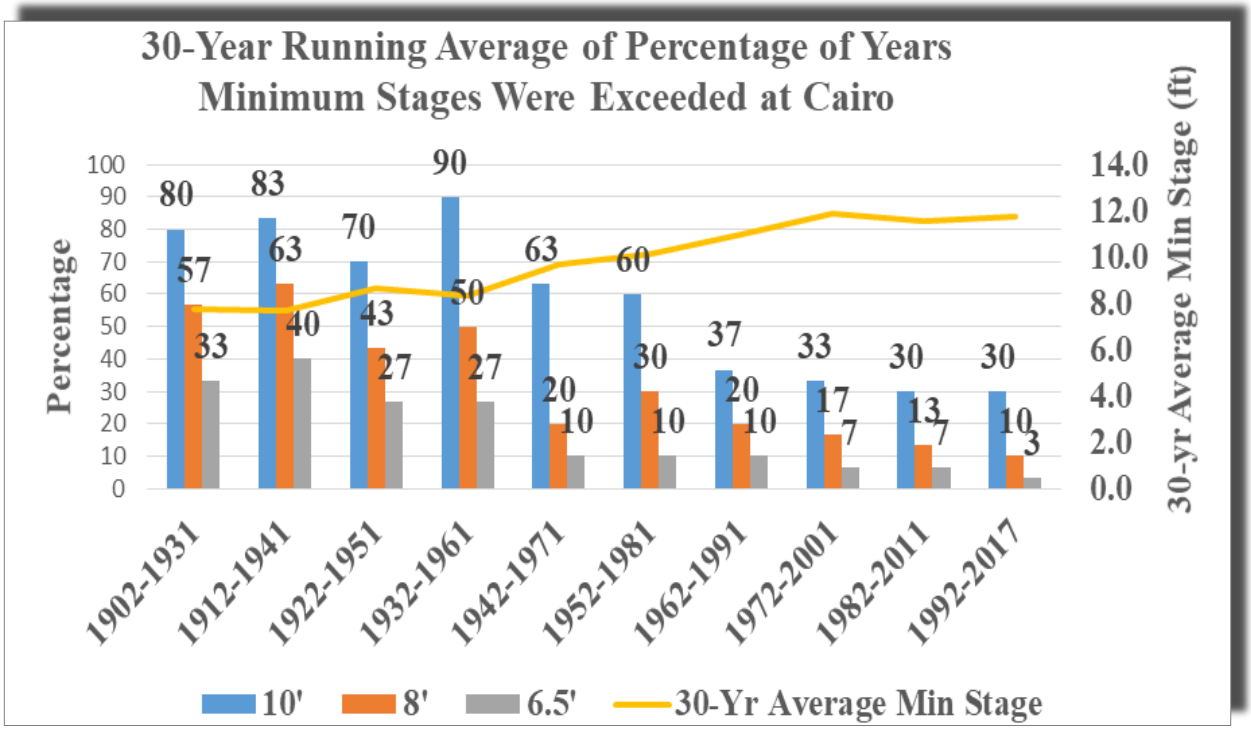


FIGURE 12. Percentage of years when minimum stages occurred at Cairo, Illinois.

2019 Regional Flooding

According to NOAA's National Centers for Environmental Information, much above average precipitation continued to be experienced into 2018/2019. The latest 12-month period from March 2018 through Feb. 2019 ranked as the wettest in the 124-year period of record over the upper Midwest, and second wettest over the Ohio, middle Mississippi and lower Missouri valleys. In fact, Sept. 2018 through Feb. 2019 ranked as the wettest six-month period on record over the entire Mississippi watershed, with the exception of the upper Missouri Valley, which experienced only above-average precipitation.

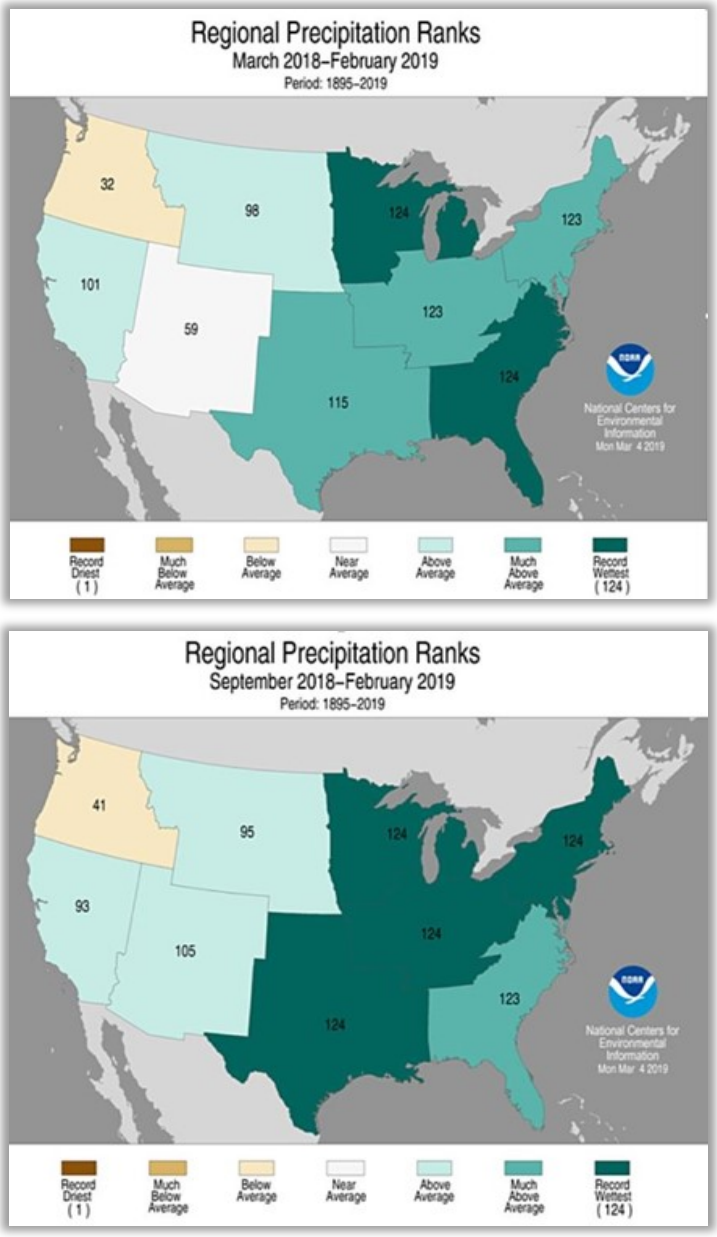
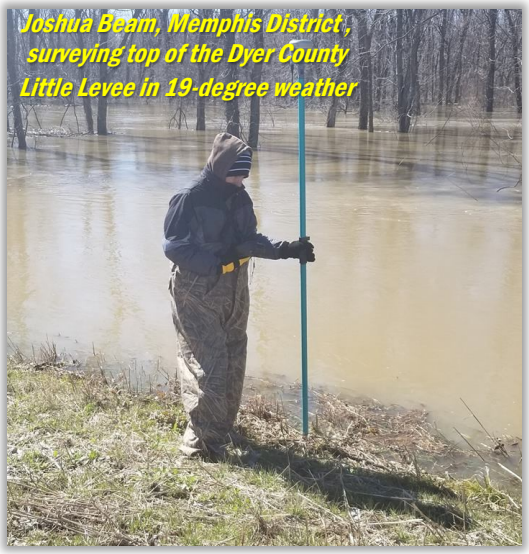


FIGURE 13: Regional rakings of precipitation during the periods March 2018-Feb. 2019 (top) and Sept. 2018-Feb. 2019 (bottom).



Bibliography

Karl, T.R. J. M. Melillo, and T. C. Peterson, Eds., 2009: *Global Climate Change Impacts in the United States.* Cambridge University Press, 189 pp.

NOAA National Centers for Environmental Information (NCEI).

Peterson, T. C. et al., 2013: Monitoring and understanding changes in heat waves, cold waves, floods and droughts in the United States: State of knowledge. *Bulletin of the American Meteorological Society*, 94, 821–834, doi:10.1175/BAMS-D-12-00066.1.

Walsh J. et al., 2014 Ch. 2 Our Changing Climate. J.M. Mellow, T (T.C.) Richmond, and G.W. Yohe, Eds., U.S. Global Change Research Program, 19-67.

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