CLIMATE CHANGE & FLOODING

Climate change is increasing flood risk in the US by rising sea levels, changing precipitation patterns, intensifying storm precipitation, and increasing rates of snow and ice melt. Worsening floods due to climate change are putting a growing number of inland and coastal communities at risk:

- Human-caused global sea level rise is increasing the number of coastal flood days in the US (Strauss et al. 2016).
- In the Mid-Atlantic, climate change contributed to widespread upward trends in stream flood magnitude and frequency since 1970 (Armstrong et al. 2014).
- Climate change is elevating flood risk across the US by increasing the frequency of extreme precipitation (Diffenbaugh et al. 2017; Lehmann et al. 2015) and intensifying hurricane rainfall (Trenberth et al. 2018; Wang et al. 2018).
- Climate change is increasing total precipitation in the Mississippi River Valley, a precursor to river flooding (Guo et al. 2019; Knutson and Zeng 2018).
- Climate change is intensifying the extreme swings between drought and flood years in California (Wang et al. 2017).

HOW IS CLIMATE CHANGE INCREASING FLOOD RISK?

Floods can be caused by heavy rainfall, rising sea levels coupled with high tides, faster and earlier snowmelt, or when dams or levees break. They can occur quickly or over a long period and may last days, weeks, or longer. Floods are the most common and among the most deadly natural disasters in the US. Just six inches of rushing water can knock over an adult and 12 inches of rushing water can carry away most cars (NOAA 2020).

The combination of melting land ice and the expansion of ocean water due to global warming has significantly increased the incidence of high tide floods and the reach of storm surge - the temporary increase in sea level due to stormy conditions.

Climate change is increasing the risk of river floods through changes in major flood precursors such as extreme precipitation, total precipitation, and snow/ice melt:

- Warmer temperatures increase evaporation of moisture into the air and allow the air to hold more moisture. This warm, water-laden air can then dump more precipitation, increasing flood risk.
- Observational data suggest climate change is likely increasing overall precipitation in the Midwest and Northeast, as well as storm precipitation in the Gulf of Mexico states.
- Long-term climate warming is causing shifts toward less snow, more rain, and earlier snowmelt, increasing early-season runoff and flood risk.

"THIS IS A NEW NORMAL. HOW MANY TIMES CAN WE HAVE A 100-YEAR FLOOD EITHER ON THE MISSISSIPPI, THE MERAMEC OR THE MISSOURI EVERY YEAR BEFORE WE REALIZE THAT THOSE TERMS ARE USELESS AND WHAT WE'VE DONE HAS SO CHANGED THE RIVER SYSTEMS THAT WE NEED TO THROW OUT ALL PRIOR MEASUREMENTS?"

- David Stokes, executive director of the Great Rivers Habitat Alliance

EVENT SPOTLIGHT: CLIMATE CHANGE AND RECENT FLOOD DISASTERS

The effect of climate change has been identified on many of the most infamous flooding disasters of the past few decades.

TIDAL FLOODING

Human-caused sea level rise is accelerating daily tidal flooding in more than 25 Atlantic and Gulf Coast cities (USGCRP 2017).

- **Miami (2015):** Flooding in Miami on September 27 inundated about two feet of normally dry land. Since 1994, sea level rise of 4.3 inches has increased the probability of two-foot tidal floods by 500 percent (Sweet et al. 2016).

STORM SURGE FLOODING

Climate change driven sea level rise has increased the likelihood of storm surge flooding.

- **New Orleans (2005):** Hurricane Katrina would have flooded 60 percent less area of New Orleans had the storm occurred around 1900, before land subsidence and climate change increased sea levels by 30 inches (Irish et al. 2014).
- **New York & New Jersey (2012):** Human-caused sea level rise extended the reach of Hurricane Sandy by 27 square miles, affecting 83,000 additional individuals living in New Jersey and New York City and adding over $2 billion in storm damage (Miller et al. 2013).

HURRICANE PRECIPITATION FLOODING

Climate change is making tropical storms and hurricanes wetter, increasing the risk of hurricane floods (Patricola and Wehner 2018). Climate change increased rainfall during Hurricanes Florence (Paerl et al. 2019), Maria (Keellings and Ayala 2019), Harvey (Trenberth et al. 2018; Wang et al. 2018), Sandy (Trenberth et al. 2015), Katrina (Trenberth et al. 2007), and during Tropical Storm Imelda (Van Oldenborgh et al. 2019).

TOTAL PRECIPITATION FLOODING

In the Midwest and along the Mississippi River Valley, significant increases in flooding are well-documented, and the change is likely due to increases in total precipitation linked to climate change (Knutson and Zeng 2018). 2019 saw the most prolonged and widespread flooding in US history due to record total precipitation along the Upper Mississippi River, Arkansas River, and Missouri River, which all drain into the Lower Mississippi.

EXTREME PRECIPITATION FLASH FLOODING

Heavy precipitation events in most parts of the US have increased in both intensity and frequency since 1901 (USGCRP 2017).

- **Louisiana (2016):** In August 2016, historic flooding from 20 to 30 inches of rain devastated a large area centered around Baton Rouge, causing over $10 billion in damages and 13 deaths (USGCRP 2018). Climate change increased the heavy rain by 20 percent (Wang et al. 2016).
- **West Virginia (2016):** In 2016, a derecho brought extreme rains, record flash flooding and 23 fatalities. Warming in the Gulf of Mexico due to climate change likely contributed to the storm's intense rainfall (Pokharel et al. 2018).
- **Missouri (2015):** Climate change increased the likelihood of extreme precipitation during Winter Storm Goliath, which dumped 9-10 inches of rain across the central US, centered southwest of St. Louis (Fosu et al. 2018).
- **Colorado (2013):** In 2013, persistent, heavy rains in Boulder broke several rainfall records and led to catastrophic flooding. Climate change increased the amount of moisture in the atmosphere (Trenberth et al. 2015) and likely increased rainfall by 30 percent (Pall et al. 2017).

EARLY SEASON RUNOFF FLOODING

In the Western US, increasing winter temperatures are leading to decreased spring snow cover and depth, earlier snowmelt and runoff, and increased flood risk (USGCRP 2018). During the 2016-2017 winter, climate change decreased Sierra Nevada snowpack by nearly 20 percent, and increased early-season runoff by 30 percent (Huang et al. 2018). That same winter, runoff in the watershed supplying the Oroville Dam prior to the Dam failure was one-third greater due to global warming (Huang et al. 2018).

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