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Fact Sheet

HEAVY PRECIPITATION IN THE U.S. AND THE CLIMATE CHANGE CONNECTION

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Since the late 1950s the United States has observed an increase in heavy precipitation.[1] Warming temperatures due to human-caused climate change has allowed the atmosphere to hold more moisture, which has been a main contributing factor to these increases.[2, 3, 4, 5, 6, 7]

Heavy precipitation, combined with factors like aging drainage infrastructure and changing land-use (e.g., more nonpermeable surfaces like asphalt), can threaten communities, economies, and human health by amplifying urban floods and flash floods.[8, 9] Additionally, heavy downpours impact agriculture through crop damage and soil erosion, and compromise city and state transportation systems across the country.[10, 11]

This fact sheet highlights regional trends, impacts, and vulnerabilities associated with heavy precipitation in the United States, examines how climate change is amplifying the frequency and severity of heavy precipitation events, and identifies some initiatives helping to address the issue.

Disclaimer: *This Fact Sheet contains preliminary research, analysis, findings, and recommendations. It is intended to stimulate timely discussion and critical feedback and to influence ongoing debate on emerging issues. Its contents may eventually be revised and published in another form.*

REGIONAL TRENDS, IMPACTS, AND VULNERABILITIES

Individual heavy precipitation events are mentioned in this section to provide information regarding the magnitude of impacts these types of events are already causing. No single heavy precipitation event can be attributed to climate change. However, research shows that climate change is increasing the frequency and intensity of these events in certain regions, and is expected to continue doing so in a warmer world.[12]

- The frequency and intensity of heavy precipitation events have increased significantly throughout most of the U.S., a trend consistent with rising temperatures.[13, 14]
  - The most significant increases in heavy precipitation have been in the Northeast and Midwest, where heavy precipitation has increased 71 percent and 37 percent, respectively, since 1958.[15]
    - During the same period, the Southeast, Great Plains, Northwest, Alaska and the Southwest have seen increases in heavy precipitation of 27 percent, 16 percent, 12 percent, 11 percent and 5 percent, respectively. Hawaii and the Pacific Islands have observed a 12 percent decrease.[16]
- Increasing heavy precipitation can stress the capacity of drainage systems and cause flooding. In cities with combined storm and sewage drainage systems (e.g., New York City, Boston, and Philadelphia), storm water and sewage can spill into waterways, threatening human health.[17]
- In regions like the Northeast, Midwest, and Great Plains, excessive runoff from significant increases in heavy downpours has frequently exceeded the capacity of storm drains and levees, resulting in flooding and accelerated erosion.[18]
- Partly due to greater heavy precipitation as well as increased total precipitation, more severe floods have occurred in some U.S. regions.[19]
  - Over the past 30 years, floods have been the most deadly weather-related hazard in the U.S., causing an average of 85 deaths per year.[20]
- A joint statement from more than 150 scientists from 36 colleges and universities in Iowa, the "Iowa Climate Statement 2013: A Rising Challenge to Iowa Agriculture," called for action to address climate change:

  "Intense rain events, the most notable evidence of climate change in Iowa, dramatically increase soil erosion, which degrades the future of agricultural production."[21, 22]
- In September 2012, a record 9.1 inches of rain fell over just 24 hours in Boulder, Colorado during a weeklong historic deluge across the state. These events caused flooding and landslides in parts of Colorado that contributed to 1,500 homes being destroyed and leaving more than 300 people missing at one point.[23, 24]
- Matt Appelbaum, Mayor of Boulder, Colorado stated (September 2013):

  "We recently experienced an incredible flood, in which a year's worth of rain fell in four days. Events like the one that struck Boulder are becoming more common all around the globe. It's clear cities are on the frontlines—we are suffering the impacts of climate change. Because of that we have to be leaders and mitigate and adapt in the face of climate change."[25]
- In June 2012, Duluth, Minnesota received a record two-day rainfall total of 7.25 inches on ground already saturated from a wetter-than-average May. The event contributed to the city experiencing a 1-in-500-year flood[i] that caused infrastructure damage estimated at $46 million.[26, 27, 28]
- Don Ness Mayor of Duluth, Minnesota stated (August 2012):

[i] According to the U.S. Geologic Survey, "100-year flood" means that the magnitude of the specific observed flood event in question had a 1 percent chance of occurring in any given year in the location where the event occurred. Similarly, a 1-in-500 year flood means the magnitude of an observed flood at the given location had a 0.2 percent chance of occurring in any given year at the specified location. Similarly, a 1-in-10 year storm means there is a 10 percent chance in any given year that the observed rainfall total will occur in the specified location. A 1-in-25 year storm has a 4 percent chance that the observed rainfall total will occur in the specified location.

"The vast majority of Americans understand that climate change is real. We just had a 500-year rain event, and unfortunately we're seeing that 500-year, 1,000-year rain events are becoming more common, and that's not by accident; there's science behind that."[29]

- Recent heavy precipitation events have caused expensive damage to transportation systems, such as roads, bridges, and rail systems, in states like Iowa, Missouri, Tennessee, and Vermont.[30]

- In Tennessee, a two-day heavy rainfall event in 2010 dropped a record 15 inches of rain in the middle and western portions of the state, and the Nashville area received more than double its previous two-day rainfall record.[31] Due to the event:[32]
  - Flood damage estimates in Davidson County were in excess of $1.5 billion, and the county experienced 40,000 power outages;
  - 115 roads were impassable in Nashville and Davidson County; and
  - 50 Nashville schools were flooded, and 2,800 businesses across the city had flood damage.

- Analysis has shown that although total annual precipitation has remained consistent throughout Iowa, there has been a significant increase in the number of days with heavy precipitation since the 1890s.[33]
  - In June 2008, the combination of low reservoir capacity, heavy rainfall, and already saturated soil from unusually wet conditions caused a record flood event in Cedar Rapids that exceeded the 1-in-500-year flood level by more than five feet. The flood caused between $5 billion and $6 billion in damages—more than $40,000 per Cedar Rapids resident—displacing 25,000 people and flooding 80 percent of government buildings and approximately 3,900 homes.[34, 35]

- In aggregate, flooding in the Midwest during 2008 caused an estimated $15 billion in losses—$8 billion from agricultural losses alone.[36]

- Approximately 772 cities in the U.S. are served by combined storm and sewage drainage systems. The intensification of heavy precipitation events together with increased runoff caused by an increase in impermeable surfaces, such as asphalt can cause degraded water quality from combined sewage overflow.[37, 38]

- On August 11, 2014, Detroit, Michigan recorded 4.57 inches of rainfall—the second highest amount it had ever recorded in a single day. Portions of five metro freeways flooded with up to 12 feet of water (which is higher than an NBA basketball hoop),[39] forcing some sections to close for up to two days.[40]

- In April 2013, a deluge in parts of Illinois (5.5 inches recorded at O'Hare International Airport) contributed to 550 reports of flood negative impacts to sewer and wastewater treatment systems in addition to 20 reports of negative impacts to drinking water supplies.[41, 42]

- In the past six years, Chicago[ii] has been hit by four storms that each met or exceeded their rainfall threshold of a 1-in-10 year storm.[43]
  - 2013, April 17–18: 5.55 inches (1-in-10 year storm)
  - 2011, July 22–23: 8.41 inches (1-in-100 year storm)
    - The 6.86 inches that fell on July 23 was the largest amount of single-day rainfall ever recorded at O'Hare International Airport
  - 2010, July 23–24: 6.43 inches (1-in-25 year storm)
  - 2008, September 13–14: 6.64 inches (1-in-25 year storm)

- Farmers, especially in the Northeast, suffer direct crop damages from increases in intense precipitation events associated with climate change.[44]

- On August 12, 2014, Baltimore, Maryland received 6.30 inches of rainfall – second only to the 7.62 inches recorded during the Chesapeake/Potomac Hurricane of 1933.[45] Baltimore's Department of Public Works stated the excessive amount of rain caused sewage overflow of more than 12 million gallons (enough to fill more than 18 Olympic swimming pools).[46, 47, 48]

[ii] According to observations from the O'Hare International Airport

- On August 13, 2014, Islip, New York received a record 13.57 inches of rain in just 24 hours. The 9.71 inches of rain that fell in just two hours during that time is roughly equal to the average rainfall Miami, Florida receives in all of June (9.67 inches) or September (9.86 inches)—Miami's two wettest months on average.[49]

THE CLIMATE CHANGE CONNECTION

- Recent studies of climate and extreme events have found that the only explanation for observed changes in climate, including the increase in heavy precipitation, over the last 50 years is human influence.[50]

- More water vapor can be held in warmer air than in cooler air, and global analysis reveals the amount of water in the atmosphere has increased – both over land and oceans.[51, 52]

  - The atmosphere's ability to hold water increases by about 4 percent for every 1°F increase in temperature.[53, 54]

  - The National Oceanic and Atmospheric Administration's hourly and daily precipitation measurements provide evidence for increasing heavy precipitation, which are supported by observed increases in atmospheric water vapor.[55, 56]

- Gerald Meehl, a senior scientist at the National Center for Atmospheric Research stated (September 2012):

  "By adding just a little bit more carbon dioxide to the climate, it makes things a little bit warmer and shifts the odds toward these more extreme events."[57]

- Jay Gulledge, senior scientist at the Center for Climate and Energy Solutions stated (September 2012):

  "We know that warming of the Earth's surface is putting more moisture in the atmosphere. We've measured it. The satellites see it."[58]

- Kevin Trenberth, a scientist at the National Center for Atmospheric Research stated (August 2014):

  "Global warming encourages what would have been a normal rainstorm to become a real downpour and increases the risk of flooding."[59]

- Heavy precipitation events are closely tied to certain types of floods (e.g., flash floods and urban floods).[60]

- Observations and models have provided strong evidence that increased heavy precipitation events in the U.S. are caused mainly by higher temperatures that have resulted in a moister atmosphere. Additional contributing factors may be land-use changes and a shift in the proportion of El Niño and La Niña events.[61]

LOCAL LEADERS RESPONDING, ACTION PLANS, AND RESOURCES

States and cities throughout the United States are taking steps to address the impacts of heavy precipitation events. From implementing upgraded and green storm water infrastructure to developing comprehensive preparedness plans to address more intense heavy precipitation, action is being taken across the nation to better prepare for heavy precipitation events and reduce the potential for costly impacts.

Chicago, IL (2014): City of Chicago: Green Stormwater Infrastructure Strategy[62]

Dane County, WI (2013): Dane County Climate Change and Emergency Preparedness[63]

Fort Lauderdale, FL (2014): Flooding and Flood Mitigation: A Partnership[64]

Philadelphia, PA (2014): City of Philadelphia Green Streets Design Manual[65]

Minnesota (2013): Minnesota Interagency Climate Adaption Team[66]

Seattle, WA (2014): Green Stormwater Infrastructure[67]

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Our Challenge

Natural resources are at the foundation of economic opportunity and human well-being. But today, we are depleting Earth's resources at rates that are not sustainable, endangering economies and people's lives. People depend on clean water, fertile land, healthy forests, and a stable climate. Livable cities and clean energy are essential for a sustainable planet. We must address these urgent, global challenges this decade.

Our Vision

We envision an equitable and prosperous planet driven by the wise management of natural resources. We aspire to create a world where the actions of government, business, and communities combine to eliminate poverty and sustain the natural environment for all people.

Our Approach

COUNT IT

We start with data. We conduct independent research and draw on the latest technology to develop new insights and recommendations. Our rigorous analysis identifies risks, unveils opportunities, and informs smart strategies. We focus our efforts on influential and emerging economies where the future of sustainability will be determined.

CHANGE IT

We use our research to influence government policies, business strategies, and civil society action. We test projects with communities, companies, and government agencies to build a strong evidence base. Then, we work with partners to deliver change on the ground that alleviates poverty and strengthens society. We hold ourselves accountable to ensure our outcomes will be bold and enduring.

SCALE IT

We don't think small. Once tested, we work with partners to adopt and expand our efforts regionally and globally. We engage with decision-makers to carry out our ideas and elevate our impact. We measure success through government and business actions that improve people's lives and sustain a healthy environment.

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