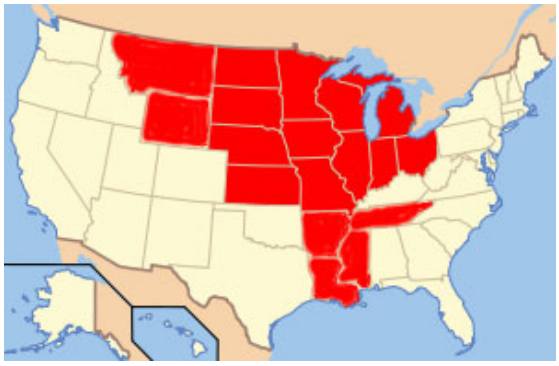
CLIMATE CENTRAL

Extreme Weather and Climate Change

Devastating deluges, record floods and deadly heat waves have raised the question of whether there's a connection between these events and global warming. **The bottom line answer is yes:** Heat waves are longer and hotter than they used to be and some regions are suffering from catastrophic drought. Heavy rains are more frequent and can be more intense, and rainfall records have been smashed. These events fit a pattern that climate scientists have long expected to appear as the result of increased greenhouse gases in our atmosphere. That doesn't mean global warming is the only culprit: extreme weather was happening before global warming began. But there's general scientific agreement that global warming has contributed to a trend toward more intense extremes of heat and precipitation around the world, is partly to blame for specific extreme weather events over the last decade and will continue to influence both in the future.



WHAT WE KNOW

- On average, the US is 2 degrees F warmer than it was 40 years ago.
- This warmer world is increasing the odds of extreme precipitation,[20,21] in part because a warmer atmosphere can hold more moisture, and release more of it during rainstorms and snowstorms.
- Heavy precipitation, both rain and snow, is happening more often than it used to.[10,4]
- Heat-related extreme events are on the rise around the globe. Manmade climate change significantly increased the odds of some specific events, including killer European heat wave of 2003[6] and the Russian heat wave of 2010.[12]
- Even small increases in average temperatures raise the risk of heat waves [6a, 6b], droughts[7] and wildfires.[8]
- Twice as many record highs have been set in the past decade as record lows, in the US. [9]
- By 2050, record highs could outpace record lows by 20 to one in the U.S. By the end of the century, the ratio could jump to 100 to one if greenhouse gas emissions continue unabated.[9]

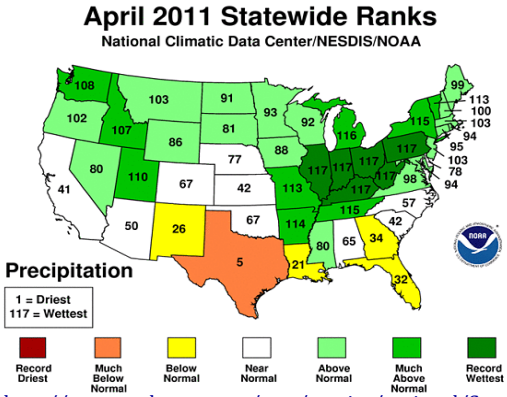
THE MIDWEST

Overview

Spring 2011 brought some of the worst flooding in history, from the Upper Midwest to the Gulf of Mexico. Snowmelt and more than three times the normal spring rainfall in the Ohio Valley made rivers, including the Ohio, Missouri and the Mississippi overflow their banks along with many smaller tributaries. The Mississippi River crested at either record or near-record levels from Illinois all the way to Louisiana.

2011 Rain and Floods

- More than 1,300 daily precipitation records were broken during April across the Midwest and South. For the month, 72 locations reported their rainiest day in any April on record and five of these stations set a new all-time record for the rainiest 24-hour period for any month, the National Climatic Data Center reported.



http://www.ncdc.noaa.gov/sotc/service/national/Statewideprank/201104-201104.gif

- On May 2, the Army Corps of Engineers breached part of the Birds Point-New Madrid Levee near where the Ohio and Mississippi Rivers come together, flooding 130,000 acres of Missouri farmland, but protecting the small Illinois town of Cairo.

- On May 9, officials opened the Bonnet Carre Spillway in Louisiana, which diverted floodwaters into Lake Pontchartrain. Later, officials also opened part of the Morganza Spillway to reduce pressure on levees that protect New Orleans from flooding.

- In Minot, North Dakota, the overflowing Souris River forced about 11,000 residents to evacuate and flooded 4,000 homes.

- Waters from the Mississippi River flooded Yazoo City, Mississippi, where the crest reached 38.7 feet, close to the record set during a devastating flood in 1927, and nearly ten feet above flood stage.

- In Memphis, the Mississippi crested at 47.9 feet, the highest there since 1937. The 2011 flood also set an all-time record in Vicksburg, Mississippi where the Mississippi crested at 57.1 feet on May 18. In Natchez, Mississippi, the river rose about four feet higher than the previous record set in 1937.

- The Missouri River also caused record floods due to above average spring precipitation and a record to near-record snowpack that contributed large amounts of river runoff. In Wyoming and Montana for the month of May, a total of 14 locations set precipitation records and seven locations set a new all-time record for the rainiest 24-hour period for any month on record.

Damage caused by the 2011 Mississippi flood

- According to the National Climate Data Center, the flooding resulted in at least $800 million of damage to Mississippi agriculture, $500 million in damage to Arkansas agriculture and $320 million in overall damages to Memphis, Tennessee.

- Overall, roughly 3.5 million acres of farmland were flooded in the Lower Mississippi Valley including 900,000 acres in Mississippi (that's 10 percent of the state's total) and 1 million in Arkansas. Across the nation, 6.8 million acres of farm and non-farm land were inundated during the spring of 2011 — one of the worst flood disasters in American history.

2011 Snow Storms

While most of the headline-grabbing snowstorms of 2011 affected Northeastern cities like New York, the Midwest was slammed as well, especially by a blizzard that struck in early February, paralyzing a region that is used to plenty of snow.

- According to NOAA, the "Groundhog Day Blizzard," which crippled travel in the Midwest and stranded motorists on Lakes Shore Drive in Chicago, dropped one to two feet in some areas, with 22 states getting at least five inches of snow.

- The Groundhog Day Blizzard was one of Chicago's top five snowstorms on record. It caused more than $1.8 billion in total losses and 36 weather-related deaths.

2011 Heat

In mid July, much of the nation sweltered under a "heat dome" that brought roasting heat and sweltering humidity to much of the eastern two thirds of the country. At its worst, more than 140 million Americans were under a heat advisory or excessive heat warning, with the heat index—a measure of discomfort that combines both heat and humidity and describes how hot it actually feels—reaching brutal levels typical of the area surrounding the Red Sea in Saudi Arabia.

References:

(1) Hegerl, G.C., F. W. Zwiers, P. Braconnot, N.P. Gillett, Y. Luo, J.A. Marengo Orsini, N. Nicholls, J.E. Penner and P.A. Stott, 2007: Understanding and Attributing Climate Change. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

(2) Santer B. D.; Mears C.; Wentz F. J.; et al. 2007. Identification of human-induced changes in atmospheric moisture content. *Proceedings of the National Academy of Sciences of the United States of America*, 104 (39), 15248-15253. DOI: 10.1073/pnas.0702872104.

(3) Trapp, R. J., N. S., Diffenbaugh, and A. Gluhovsky, 2009. Transient response of severe thunderstorm forcing to elevated greenhouse gas concentrations. *Geophys. Res. Lett.*, 36, L01703. DOI:10.1029/2008GL036203.

(4) Trenberth, K.E., P.D. Jones, P. Ambenje, R. Bojariu, D. Easterling, A. Klein Tank, D. Parker, F. Rahimzadeh, J.A. Renwick, M. Rusticucci, B. Soden and P. Zhai, 2007. Observations: Surface and Atmospheric Climate Change. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

(5a) Stott, P. A., Gillett, N. P., Hegerl, G. C., Karoly, D. J., Stone, D. A., Zhang, X. and Zwiers, F., 2010. Detection and attribution of climate change: a regional perspective. *Interdisciplinary Reviews: Climate Change*, 1, 192–211. DOI: 10.1002/wcc.34.

(5b) Meehl, G.A., T.F. Stocker, W.D. Collins, P. Friedlingstein, A.T. Gaye, J.M. Gregory, A. Kitoh, R. Knutti, J.M. Murphy, A. Noda, S.C.B. Raper, I.G. Watterson, A.J. Weaver and Z.-C. Zhao, 2007, Global Climate Projections. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

(6a) Christidis, N., P.A. Stott, and S. Brown, 2011. The role of human activity in the recent warming of extremely warm daytime temperatures. *Journal of Climate*, 24, 1922-1930. DOI:10.1175/2011JCLI4150.1

(6b) Stott, P. A.; Stone, D. A; Allen, M. R., 2004. Human contribution to the European heatwave of 2003. *Nature*, 432, 610. DOI: 10.1038/nature04099.

(7) Dai, A. 2011. Drought under global warming: a review. *Interdisciplinary Reviews: Climate Change*, 2 (1), 46-65. DOI: 10.1002/wcc.81.

(8) Gillett, N.P.; Weaver, A.J.; Zwiers, F.W. et al. 2004. Detecting the effect of climate change on Canadian forest fires. *Geophys. Res. Lett.,* 31 (18), L18211. DOI: 10.1029/2004GL020044.

(9) Meehl, G. A.; Tebald, C.; Walton Guy; et al. 2009. Relative increase of record high maximum temperatures compared to record low minimum temperatures in the U. S.. *Geophys. Res. Lett.,* 36, L23701. DOI: 10.1029/2009GL040736.

(10) Alexander, L. V.; Zhang, X.; Peterson, T. C.; et al. Global observed changes in daily climate extremes of temperature and precipitation. *J. Geophys. Res.,* 111 (D5), D05109. DOI: 10.1029/2005JD006290.

(11) Stott, P. A.; Jones, G. S.; Christidis, N., et al., 2011. Single-step attribution of increasing frequencies of very warm regional temperatures to human influence. *Atmospheric Science Letters*, 12 (2), 220-227. DOI: 10.1002/asl.315.

(12) Rahmstorf, S. and D. Coumou, 2011. Increase in extreme events in a warming world. *Proceeding of the National Academy of Sciences of the United States of America*, 108 (44) 17905-17909. doi 10.1073/pnas.1101766108.

(13) Confalonieri, U., Menne, B., Akhtar, R., Ebi, K. L., Hauengue, M., Kovats, R. S., Revich, R.S., Woodward, A., 2007. Human health. *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 391-431.

(14) Easterling, W.E., Aggarwal, P.K., Batima, P., Brander, K.M., Erda, L., Howden,, S.M., Kirilenko, A., Morton, J., Soussana, J.-F., Schmidhuber, J. , Tubiello, F. N., 2007. Food, fibre and forest products. *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 273-313.

(15) Barnett, T.P., Pierce, D.W., Hidalgo, H.G., et al. 2008. Human-induced changes in the hydrology of the western United States. *Science*. 319 (5866), 1080-1083. DOI: 10.1126/science.1152538.

(16) Littell, J.S., McKenzi, D., Peterson, D.L.; et al., 2009. Climate and wildfire area burned in western U. S. ecoprovinces, 1916-2003. *Ecological Applications*, 19 (4), 1003-1021. DOI: 10.1890/07-1183.1.

(17) Solomon, S. et al., 2011. Climate Stabilization Targets, *NRC Report*. The National Academies Press. Washington, DC,p 286.

(18) Hoerling, M., Quan, X.-W., Eischeid, J., 2009. Distinct causes for two principal US droughts of the 20th century. *Geophys. Res. Lett.* 36, L19708. DOI: 10.1029/2009GL039860.

(19) Dominguez, F., Kumar, P., 2005. Dominant modes of moisture flux anomalies over North America. *J. Hydrometeorology,* 6 (2), 194-209. DOI: 10.1175/JHM417.1.

(20) Min S., Zhang, X., Zwiers, F., Hegerl. G., 2011. Human contribution to more-intense precipitation extremes. *Nature,* 470, 378–381. DOI:10.1038/nature09763.

(21) Pall, P., Aina, T., Stone, D. A., et al., 2011. Anthropogenic greenhouse gas contribution to flood risk in England and Wales in autumn 2000. *Nature*, 470 (7334), 382-385. DOI: 10.1038/nature09762.