

Hundred-Year Forecast: Drought

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BY many measurements, this summer's drought is one for the record books. But so was last year's drought in the South Central states. And it has been only a decade since an extreme five-year drought hit the American West. Widespread annual droughts, once a rare calamity, have become more frequent and are set to become the "new normal."

Until recently, many scientists spoke of climate change mainly as a "threat," sometime in the future. But it is increasingly clear that we already live in the era of human-induced climate change, with a growing frequency of weather and climate extremes like heat waves, droughts, floods and fires.

Future precipitation trends, based on climate model projections for the coming fifth assessment from the Intergovernmental Panel on Climate Change, indicate that droughts of this length and severity will be commonplace through the end of the century unless human-induced carbon emissions are significantly reduced. Indeed, assuming business as usual, each of the next 80 years in the American West is expected to see less rainfall than the average of the five years of the drought that hit the region from 2000 to 2004.

That extreme drought (which we have analyzed in a new study in the journal *Nature-Geoscience*) had profound consequences for carbon sequestration, agricultural productivity and water resources: plants, for example, took in only half the carbon dioxide they do normally, thanks to a drought-induced drop in photosynthesis.

In the drought's worst year, Western crop yields were down by 13 percent, with many local cases of complete crop failure. Major river basins showed 5 percent to 50 percent reductions in flow. These reductions persisted up to three years after the drought ended, because the lakes and reservoirs that feed them needed several years of average rainfall to return to predrought levels.

In terms of severity and geographic extent, the 2000-4 drought in the West exceeded such legendary events as the Dust Bowl of the 1930s. While that drought saw intervening years of normal rainfall, the years of the turn-of-the-century drought were consecutive. More seriously still, long-term climate records from tree-ring chronologies show that this drought was the most severe event of its kind in the western United States in the past 800 years. Though there have been many extreme droughts over the last 1,200 years, only three other events have been of similar magnitude, all during periods of "mega-droughts."

Most frightening is that this extreme event could become the new normal: climate models point to a warmer planet, largely because of greenhouse gas emissions. Planetary warming, in turn, is expected to

create drier conditions across western North America, because of the way global-wind and atmospheric-pressure patterns shift in response.

Indeed, scientists see signs of the relationship between warming and drought in western North America by analyzing trends over the last 100 years; evidence suggests that the more frequent drought and low precipitation events observed for the West during the 20th century are associated with increasing temperatures across the Northern Hemisphere.

These climate-model projections suggest that what we consider today to be an episode of severe drought might even be classified as a period of abnormal wetness by the end of the century and that a coming mega-drought — a prolonged, multi-decade period of significantly below-average precipitation — is possible and likely in the American West.

The current drought plaguing the country is worryingly consistent with these expectations. Although we do not attribute any single event to global warming, the severity of both the turn-of-the-century drought and the current one is consistent with simulations accounting for warming from increased greenhouse gases. The Northern Hemisphere has just recorded its 327th consecutive month in which the temperature exceeded the 20th-century average. This year had the fourth-warmest winter on record, with record-shattering high temperatures in March. And 2012 has already seen huge wildfires in Colorado and other Western states. More than 3,200 heat records were broken in June alone.

And yet that may be only the beginning, a fact that should force us to confront the likelihood of new and painful challenges. A mega-drought would present a major risk to water resources in the American West, which are distributed through a complex series of local, state and regional water-sharing agreements and laws. Virtually every drop of water flowing in the American West is legally claimed, sometimes by several users, and the demand is expected to increase as the population grows.

Many Western cities will have to fundamentally change how they acquire and use water. The sort of temporary emergency steps that we grudgingly adopt during periods of low rainfall — fewer showers, lawn-watering bans — will become permanent. Some regions will become impossible to farm because of lack of irrigation water. Thermoelectric energy production will compete for limited water resources.

There is still time to prevent the worst; the risk of a multi-decade mega-drought in the American West can be reduced if we reduce fossil-fuel emissions. But there can be little doubt that what was once thought to be a future threat is suddenly, catastrophically upon us.

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