MIDWEST

Farming,manufacturing,and forestry characterize the Midwest. The Great Lakes form the world's largest freshwater lake system,providing a major recreation area as well as a regional water transportation system with access to the Atlantic Ocean via the St.Lawrence Seaway. The region encompasses the headwaters and upper basin of the Mississippi River and most of the length of the Ohio River, both critical water sources and means of industrial transportation providing an outlet to the Gulf of Mexico. The Midwest contains some of the richest farmland in the world and produces most of the Nation's corn and soybeans. It also has important metropolitan centers,including Chicago and Detroit. Most of the largest urban areas in the region are found along the Great Lakes and major rivers. The "North Woods" are a large source of forestry products and have the advantage of being situated near the Great Lakes,providing for easy transportation.

Observed Climate Trends

Over the 20th century, the northern portion of the Midwest,including the upper Great Lakes,has warmed by almost 4ºF (2ºC),while the southern portion,along the Ohio River valley, has cooled by about 1ºF (0.5ºC). Annual precipitation has increased,with many of the changes quite substantial,including as much as 10 to 20% increases over the 20th century. Much of the precipitation has resulted from an increased rise in the number of days with heavy and very heavy precipitation events. There have been moderate to very large increases in the number of days with excessive moisture in the eastern portion of the basin.

Scenarios of Future Climate

During the 21st century, models project that temperatures will increase throughout the Midwest,and at a greater rate than has been observed in the 20th century. Even over the northern portion of the region,where warming has been the largest,an accelerated warming trend is projected for the 21st century, with temperatures increasing by 5 to 10ºF (3 to 6ºC). The average minimum temperature is likely to increase as much as 1 to 2ºF (0.5 to 1ºC) more than the maximum temperature. Precipitation is likely to continue its upward trend,at a slightly accelerated rate;10 to 30% increases are projected across much of the region. Despite the increases in precipitation,increases in temperature and other meteorological factors are likely to lead to a substantial increase in evaporation,causing a soil moisture deficit, reduction in lake and river levels,and more drought-like conditions in much of the region. In addition,increases in the proportion of precipitation coming from heavy and extreme precipitation are very likely.

KEY ISSUES

- **Reduction in Lake and River Levels**
- **Health and Quality of Life in Urban Areas**
- **Agricultural Shifts**
- **Changes in Semi-natural and Natural Ecosystems**

Climate Extremes Create Critical Transportation Problems

Climate extremes in the Midwest can drastically impede the highly weather-sensitive transportation systems that serve not only the region, but the entire nation. Chicago is the nation's rail hub handling much of the nation freight traffic. Barges operating on the Mississippi River system, that includes the Ohio, Illinois, and Missouri Rivers, handle a large fraction of the country's bulk commodities, such as grain and coal.

Prolonged heavy rainfall in the spring and summer of 1993 produced extensive flooding across nine states in the upper Midwest. The flood waters poured over and through many levees and inundated numerous floodplains that many of the key rail lines cross. The flood waters became an

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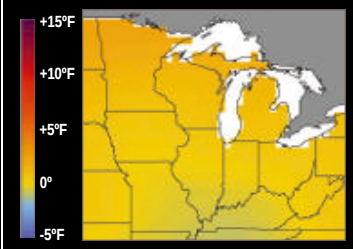
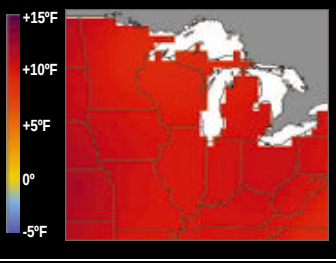
Temperature Change - 20th & 21st Centuries

Observed 20th

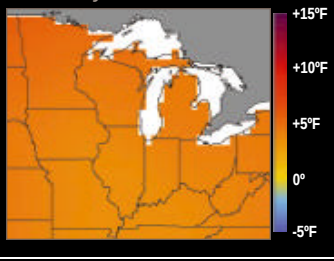


Temperatures in the Midwest have increased, with the largest observed changes for the region in Minnesota and the Upper Peninsula of Michigan. Model scenarios suggest further increases over the 21st century from near 5ºF (Hadley model) to more than 10ºF (Canadian model).

Canadian Model 21st



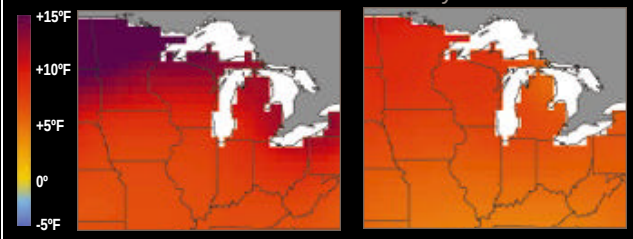
Hadley Model 21st



Winter Minimum Temperature Change
21st Century Average

Canadian Model

Hadley Model



Both climate models indicate that the northern part of the Midwest will experience the largest increases in winter temperatures. The Canadian Model suggests the greatest increases, approaching 15ºF in Minnesota and the Upper Peninsula of Michigan.

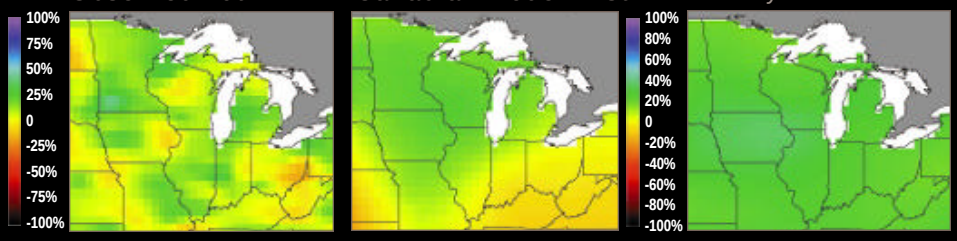
Precipitation Change - 20th & 21st Centuries

On average, Midwest precipitation over the 20th century has increased.

Observed 20th

Canadian Model 21st

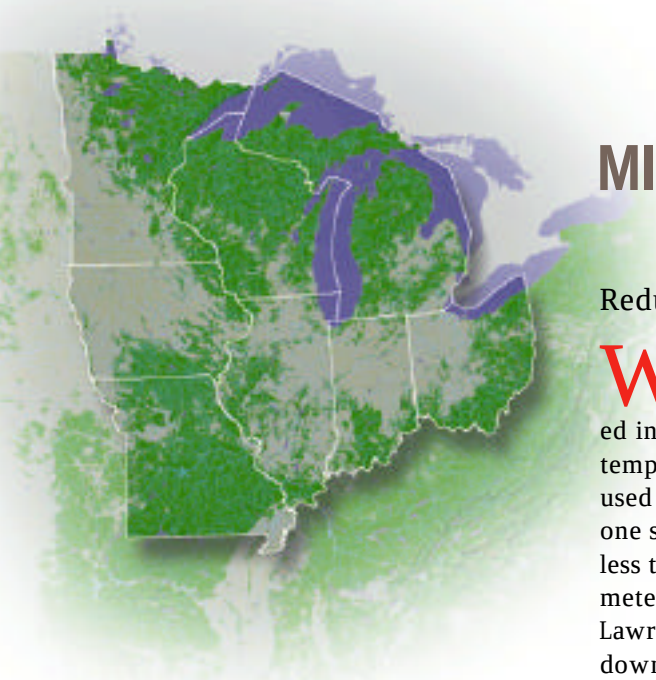
Hadley Model 21st



The Hadley model indicates that this trend will continue, resulting in increases of about 25% from the present. The Canadian model suggests that these increases will be confined to the northern and western parts of the region.

absolute barrier to surface transportation in the region for more than six weeks. Train traffic had to be rerouted around the flood area, resulting in long delays and large costs to manufacturing. River barge traffic suffered a similar fate with the additional costs to shipping and manufacturing approaching $2 billion.

This came on the heels of the 1988 drought that also had a major impact on barge shipping due to low river levels, illustrating the sensitivity of transportation systems to both wet and dry climate extremes.



MIDWEST KEY ISSUES

Reduction in Lake and River Levels

Water levels,supply, quality, and water-based transportation and recreation are all climate-sensitive issues affecting the region. Despite the projected increase in precipitation,increased evaporation due to higher summer air temperatures is likely to lead to reduced levels in the Great Lakes.Of 12 models used to assess this question,11 suggest significant decreases in lake levels while one suggests a small increase. The total range of the 11 models' projections is less than a one-foot increase to more than a five-foot decrease. A five-foot (1.5-meter) reduction would lead to a 20 to 40% reduction in outflow to the St. Lawrence Seaway. Lower lake levels cause reduced hydropower generation downstream,with reductions of up to 15% by 2050. An increase in demand for water across the region at the same time as net flows decrease is of particular concern. There is a possibility of increased national and international tension related to increased pressure for water diversions from the Lakes as demands for water increase. For smaller lakes and rivers, reduced flows are likely to cause water quality issues to become more acute. In addition,the projected increase in very heavy precipitation events will likely lead to increased flash flooding and worsen agricultural and other non-point source pollution as more frequent heavy rains wash pollutants into rivers and lakes. Lower water levels are likely to make water-based transportation more difficult with increases in the costs of navigation of 5 to 40%. Some of this increase will likely be offset as reduced ice cover extends the navigation season. Shoreline damage due to high lake levels is likely to decrease 40 to 80% due to reduced water levels.

The projected increase in very heavy precipitation events will likely worsen agricultural and other non-point source pollution as more frequent heavy rains wash pollutants into rivers and lakes.

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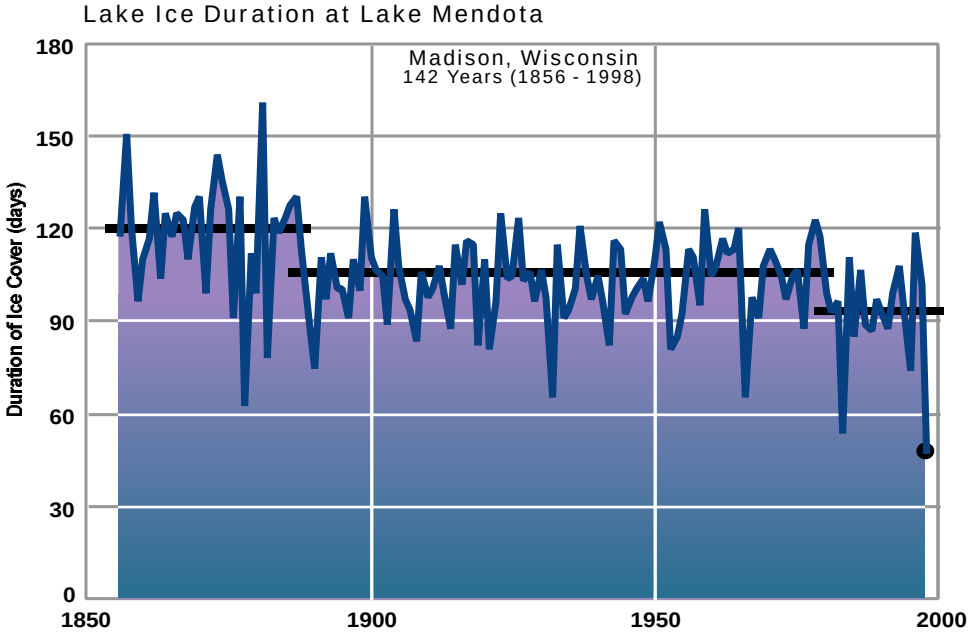
Adaptations: A reduction in lake and river levels would require adaptations such as re-engineering of ship docks and locks for transportation and recreation. If flows decrease while demand increases,international commissions focusing on Great Lakes water issues are likely to become even more important in the future.Improved forecasts and warnings of extreme precipitation events could help reduce some related impacts.



Lake ice duration has decreased by nearly one month over the past 150 years, with a record low in the winter of 1997-98. This is consistent with observed increases in temperature.

Health and Quality of Life in Urban Areas

A reduction in extremely low temperatures and an increase in extremely high temperatures are expected. Thus,a reduced risk of life-threatening cold and an increased risk of life-threatening heat are likely to accompany warming. Reduced expenditures on snow and ice removal and fewer snow and ice related accidents and delays are likely. During the summer, however, in cities,heat-related stresses are very likely to be exacerbated by the urban heat island effect,a phenomenon in which cities remain much warmer than surrounding rural areas. This elevates nighttime temperatures,and in combination with the greater expected rise of nighttime temperatures compared to those of daytime,there will be less relief at night during heat waves. Elevated nighttime temperatures were a notable characteristic of the 1995 heat wave that resulted in over 700 deaths in Chicago. In addition,during heat waves in the Midwest, air pollutants are trapped near the surface,as atmospheric ventilation is reduced. Without strict attention to regional emissions of air pollutants,the undesirable combination of extreme heat and unhealthy air quality is likely to result. There is also a possibility of an increased risk of water-borne diseases with increases in extreme precipitation events,and increased insect- or tick-borne diseases,such as St.Louis encephalitis. Recreational activities will very likely shift as cold-season recreation such as skiing,snowmobiling,ice skating, and ice-fishing,are reduced,and warm-season recreation such as swimming,hiking,and golf, are expanded,although during mid-summer, these activities are likely to be affected by excessive heat.

Adaptations: Active responses,such as those taken by Chicago during the 1999 heat wave,are likely to help reduce the death toll due to extreme heat. Separate storm water and sewer lines and other appropriate preventative measures can help mitigate the possible increased risk of water-borne diseases.

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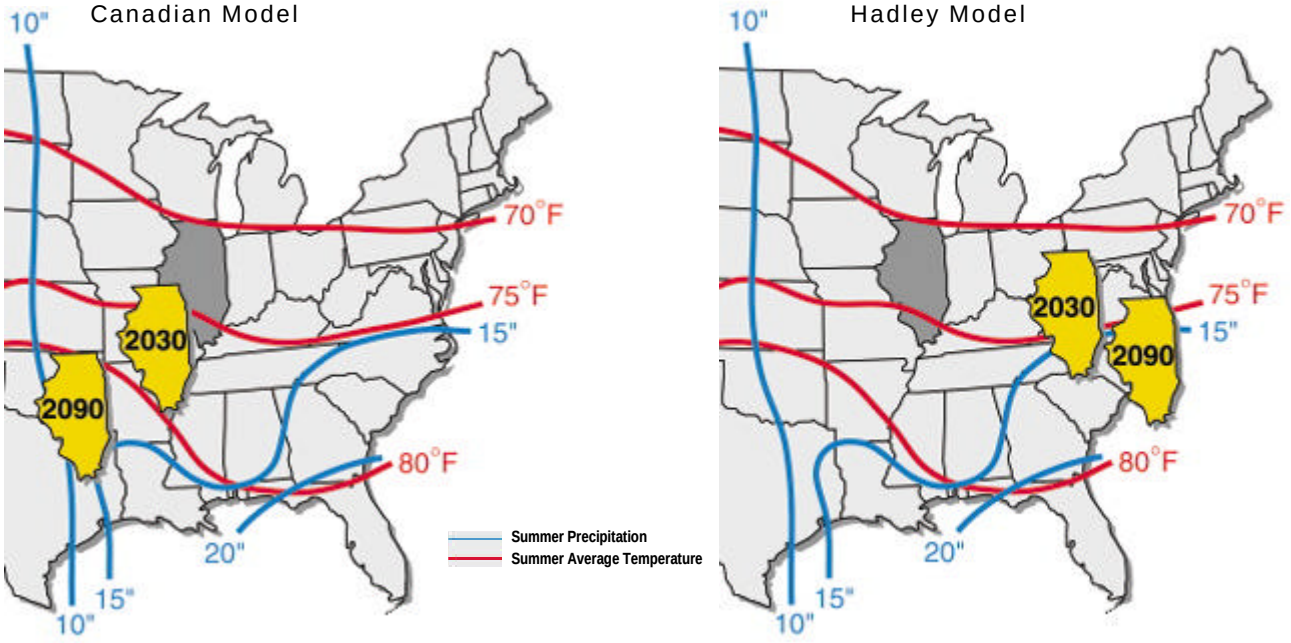


Illustration of how the summer climate of Illinois would shift under the Canadian and Hadley model scenarios. Under the Canadian scenario, the summer climate of Illinois would become more like the current climate of southern Missouri in 2030 and more like Oklahoma's current climate in 2090. The primary difference in the resulting climates of the two models relates to the amount of summer rainfall.

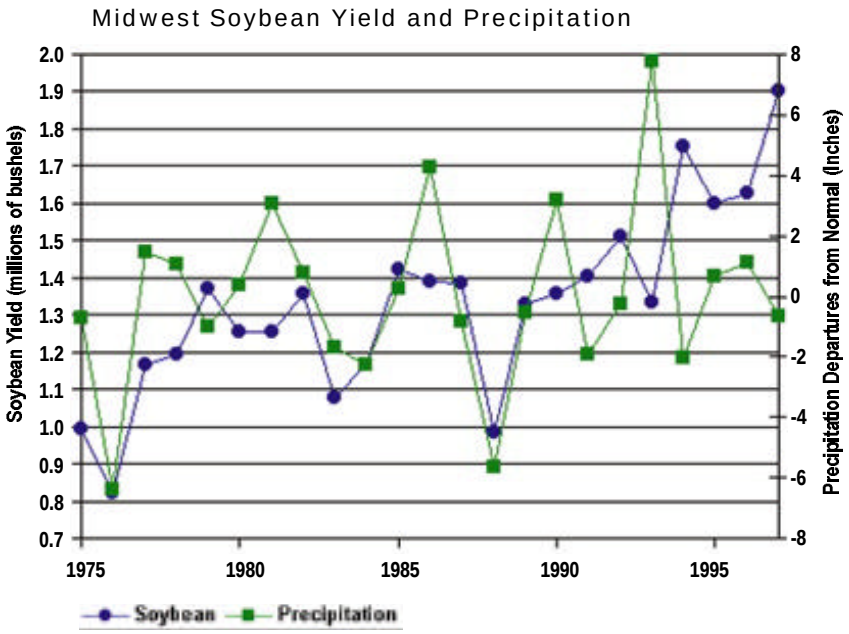
MIDWEST KEY ISSUES

Agricultural Shifts

Agriculture is of vital importance to this region,the nation,and the world. It has exhibited a capacity to adapt to moderate differences in growing season climate,and it is likely that agriculture would be able to continue to adapt. With an increase in the length of the growing season, double cropping,the practice of planting a second crop after the first is harvested,is likely to become more prevalent. The CO_2 fertilization effect is likely to enhance plant growth and contribute to generally higher yields. The largest increases are projected to occur in the northern areas of the region,where crop yields are currently temperature limited. However, yields are not likely to increase in all parts of the region. For example,in the southern portions of Indiana and Illinois,corn yields are likely to decline,with 10-20% decreases projected in some locations. Consumers are likely to pay lower prices due to generally increased yields,while most producers are likely to suffer reduced profits due to declining prices. Increased use of pesticides and herbicides are very likely to be required and to present new challenges.

Adaptations: Plant breeding programs can use skilled climate predictions to aid in breeding new varieties for the new growing conditions. Farmers can then choose varieties that are better attuned to the expected climate. It is likely that plant breeders will need to use all the tools of plant breeding,including genetic engineering,in adapting to climate change.Changing planting and harvest dates and planting densities,and using integrated pest management, conservation tillage,and new farm technologies are additional options. There is also the potential for shifting or expanding the area where certain crops are grown if climate conditions become more favorable. Weather conditions during the growing season are the primary factor in year-to-year differences in corn and soybean yields. Droughts and floods result in large yield reductions;severe droughts,like the drought of 1988, cause yield reductions of over 30%. Reliable seasonal forecasts are likely to help farmers adjust their practices from year to year to respond to such events.

Farm flooded by Mississippi river in 1993.



The relationship between Midwest soybean yield and precipitation is shown here. Soybean yields in thousands of bushels are shown as the differences from the average yield in recent decades. Precipitation is the difference from the 1961-90 average precipitation. Note that lower yields result from both extreme wet and extreme dry conditions.

Changes in Semi-natural and Natural Ecosystems

The upper Midwest has a unique combination of soil and climate that allows for abundant coniferous tree growth. Higher temperatures and increased evaporation will likely reduce boreal forest acreage,and make current forestlands more susceptible to pests and diseases. It is likely that the southern transition zone of the boreal forest will be susceptible to expansion of temperate forests, which in turn will have to compete with other land use pressures. However, warmer weather (coupled with beneficial effects of increased CO_2),are likely to lead to an increase in tree growth rates on marginal forestlands that are currently temperature-limited. Most climate models indicate that higher air temperatures will cause greater evaporation and hence reduced soil moisture, a situation conducive to forest fires. As the 21st century progresses,there will be an increased likelihood of greater environmental stress on both deciduous and coniferous trees,making them susceptible to disease and pest infestation,likely resulting in increased tree mortality.

As water temperatures in lakes increase,major changes in freshwater ecosystems will very likely occur, such as a shift from cold water fish species,such as trout,to warmer water species,such as bass and catfish. Warmer water is also likely to create an environment more susceptible to invasions by non-native species. Runoff of excess nutrients (such as nitrogen and phosphorus from fertilizer) into lakes and rivers is likely to increase due to the increase in heavy precipitation events. This, coupled with warmer lake temperatures,is likely to stimulate the growth of algae,depleting the water of oxygen to the detriment of other living things. Declining lake levels are likely to cause large impacts to the current distribution of wetlands. There is some chance that some wetlands could gradually migrate,but in areas where their migration is limited by the topography, they would disappear. Changes in bird populations and other native wildlife have already been linked to increasing temperatures and more changes are likely in the future. Wildlife populations are particularly susceptible to climate extremes due to the effects of drought on their food sources.

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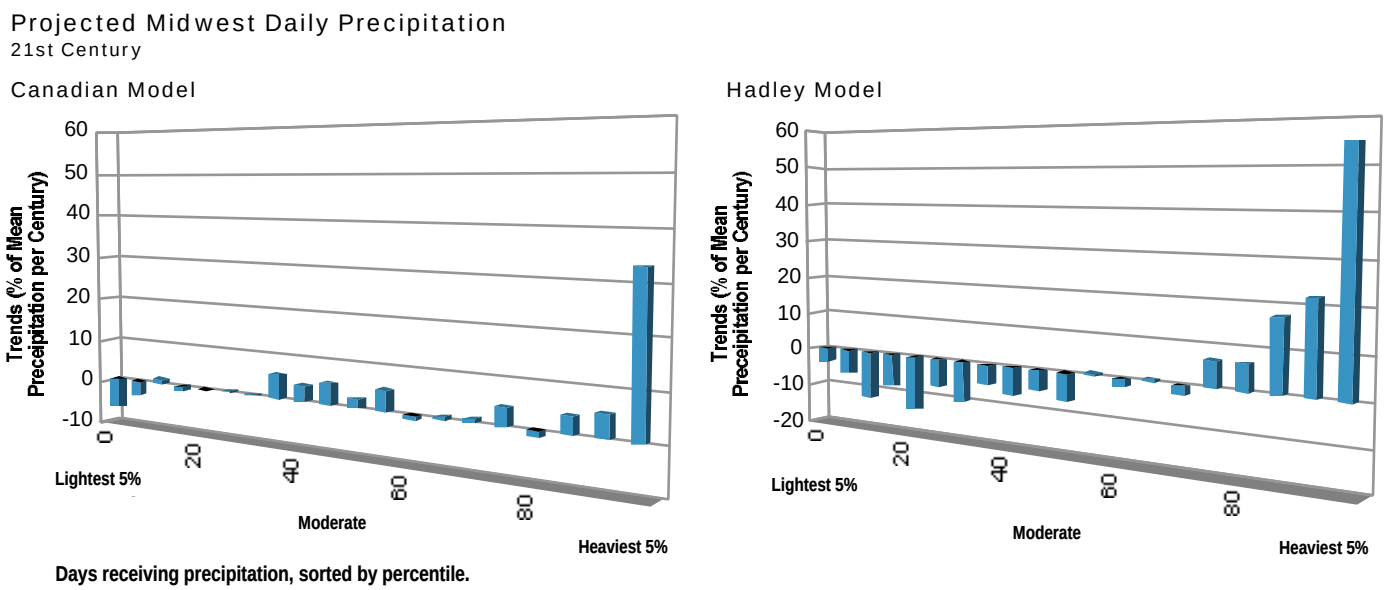

Annual trends in daily precipitation by percentile for the Canadian and Hadley model scenarios for the 21st century. Notice the largest trend is in the heaviest daily precipitation amount for both model simulations, indicating that most of the projected increase in annual precipitation will be due to an increase in precipitation on days already receiving large amounts.