The Potential Impacts of Climate Change on Dayton, Ohio

GLISA
GREAT LAKES INTEGRATED SCIENCES + ASSESSMENTS
GLAA-C
Great Lakes Adaptation Assessment for Cities

Photo by: Jim Crotty

Key Challenges

Known as the birthplace of aviation, Dayton is a community rich in history and innovation. Located in the Miami-Valley, Dayton serves as the county seat of Montgomery County and a key economic engine for much of Ohio. The larger Dayton Metropolitan Statistical Area is the fourth largest contributor to statewide gross domestic product.[i]

Recognizing the importance of Dayton, *Site Selection* magazine ranked the region as the #1 medium-sized metropolitan area in the United States for economic development in both 2008 and 2009.[ii] Additionally, in 2010, Bloomberg Businessweek ranked Dayton as one of the best places for college graduates to find employment.[iii]

Unfortunately, changing weather and long-term climate conditions could reduce the vitality of the Dayton region, presenting new or enhancing existing challenges. While Dayton will face many of the same changes in climate as the surrounding area, the city's specific vulnerabilities will be determined primarily by factors such as land use and zoning, existing infrastructure design, current policies, the socioeconomic capacity of residents, the flexibility of businesses, and the strength of existing social networks. The presence or absence of these characteristics (as well as others) will either help Dayton build its resilience or pose obstacles to the city's efforts to prepare for climate change.

There are many existing and potential future impacts of climate change that could affect Dayton, including:

- *As temperatures rise, the probability of heat waves and hot days will grow, increasing the risk of heat-related illnesses.*
- *Declining air quality, leading to significant public health impacts.*
- *As severe rainstorms become more frequent and intense, there may be an increased risk of sewage overflows and water contamination.*
- *Changes in the productivity and distribution of agriculture and natural systems.*
- *Direct damage to infrastructure from more extreme weather events and increasing demands for services during extreme events.*

Heat Waves and Hot Days

In Ohio, the average annual temperature has increased by 0.07^{o}F per decade over the last century (Figure 1).[iv] Over the next few decades, temperatures are projected to continue rising, with an increase between 3^{o}F to 4^{o}F expected by mid-century and a 12^{o}F increase in average summer temperatures expected by end of this century (Figure 2).[v]

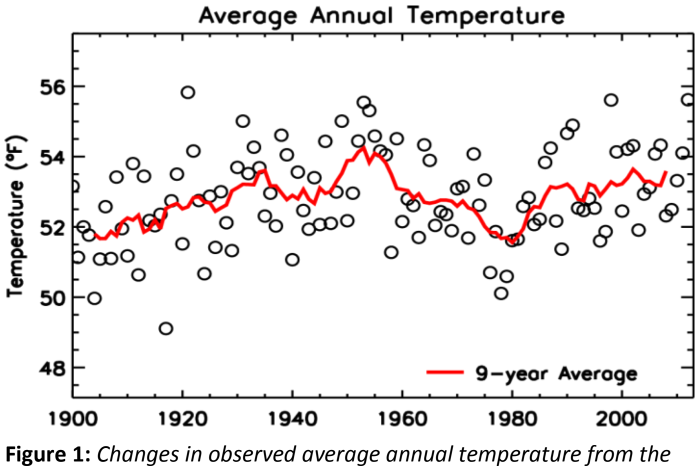

Figure 1: *Changes in observed average annual temperature from the Dayton International Airport between 1950 and 2010. Open circles represent annual average temperatures observed and the red line represents the nine-year running average. Over this time period, there has been a roughly 0.2^{o}F increase in average annual temperature, with the greatest increase noticeable in winter (0.8^{o}F increase in average annual winter temperatures). Data source: NCDC, Station ID 332075.*

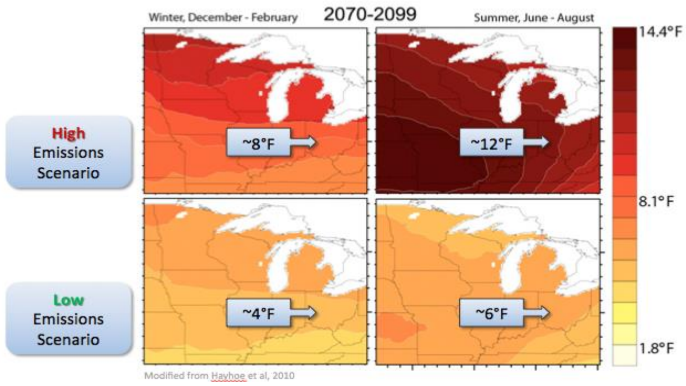

Figure 2: *Projected changes in temperature for southwest Ohio based on both a high greenhouse gas emissions scenario (top row) and a low greenhouse gas emissions scenario (bottom row) for the winter and summer seasons. Modified from Hayhoe et al., 2010 by the Great Lakes Integrated Sciences and Assessment. Under the high emissions scenario, temperatures in winter for southeast Ohio could be 8°F higher than current temperatures by end of the century. Summer temperatures under the high emission scenario could be up to 12°F warmer than current temperatures.*

Small increases in average annual temperatures over time can greatly increase the probability of heat waves and hot days. While no specific data was available for Dayton, data for Cincinnati and Cleveland show that these cities are projected to experience more than 85 days and 60 days, respectively, of temperatures over 90°F by end of the century (Figure 3).[iv] Temperature increases of this magnitude will likely lead to at least two heat waves per summer in Cincinnati of similar intensity to the 1995 Chicago heat wave that caused hundreds of deaths.[iv] Given the geographic proximity to Cincinnati and the similarity in climate projections for the region, it is likely that Dayton will also experience a heightened risk of heat waves due to increasing temperatures. With more frequent and more intense heat waves, there is a greater risk of heat-related illness and death.

In addition, increases in temperature combined with changes in humidity can alter the way outdoor temperatures "feel". Figure 4 demonstrates how summer temperatures in Ohio could change under both a low and a high greenhouse gas emissions scenario.[vi]

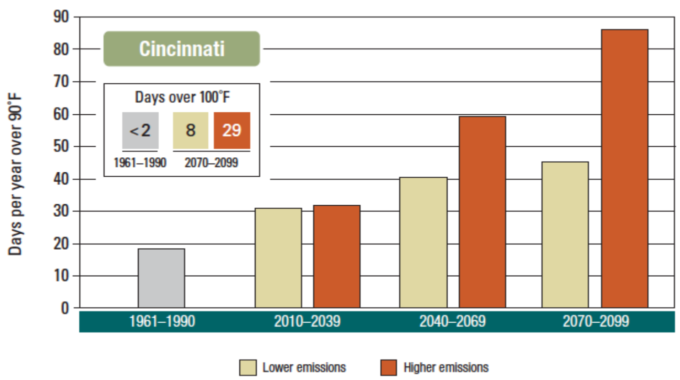

Figure 3: *The larger Dayton region is projected to see a dramatic increase in the number of hot days exceeding 90°F (inset, 100°F), assuming current global greenhouse gas emissions trends continue (higher emissions). Assuming greenhouse gas emissions are significantly curtailed (lower emissions), the number of hot days will still increase but will be far fewer than under a high emissions scenario.[IV]*

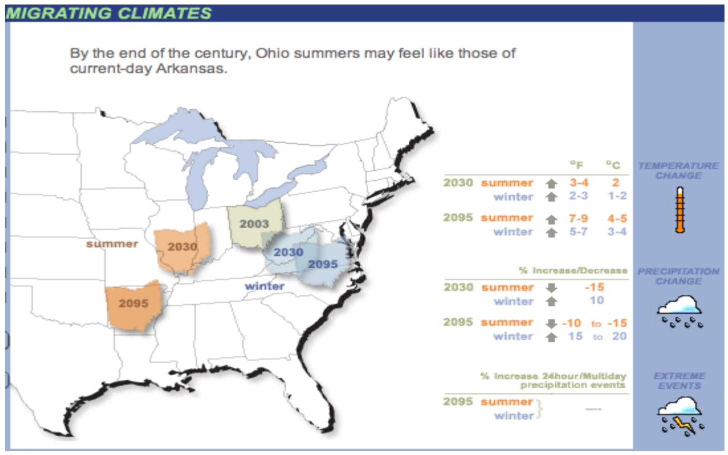

Figure 4: *This map indicates what temperatures in Ohio might "feel" like under a high and a low greenhouse gas emissions scenario. Under the low emissions scenario (light blue), by 2030, temperatures in Ohio could feel like those in West Virginia and by 2095, temperatures could feel like those currently experienced in Virginia. Under a high greenhouse gas emissions scenario, temperatures in Ohio by 2030 could feel more like southern Illinois and by end of the century, temperatures would feel more like those currently experienced in Arkansas.[V]*

Heat-related Illness and Death

Health conditions that can be triggered or exacerbated during hot weather range from mild heat-rashes to heat exhaustion, heatstroke, and death.[vii,viii] Rising overnight temperatures during heat waves present the greatest risk for more severe illnesses, since residents are less able to find relief from sweltering temperatures.[ix,x]

A number of factors raise the risk of heat-related illness in urban environments. People of lower socioeconomic status and people that live in areas of higher population density are at greater risk of exposure to extreme heat. In these neighborhoods, heat island effects amplify hot weather, vegetation tends to be sparse and provides little natural shade, and homes are less likely to have air conditioning.[xi,xii,xiii,xiv] In Dayton, the median household income is only $28,843 (nearly $24,000 less than the U.S. national average), 26.5 percent of families live below the poverty line (the national average is 10.5 percent), and a significant portion of the population spends more than 30 percent of their income on rent or monthly mortgage payments.[xv] All of these factors combine to enhance the vulnerability of many of Dayton's residents to heat by reducing their economic ability to effectively respond during heat waves.

Air Quality

Ground-level ozone is a dangerous air pollutant and the main component of photochemical smog. Elevated ground-level ozone concentrations reduce lung function while aggravating heart and respiratory conditions. As ozone levels rise, so too does the number of hospitalizations for respiratory and cardiovascular conditions.[xvi]

The production of ground-level ozone increases with the presence of local sources of fossil fuel emissions and by temperatures over approximately 90°F.[xvii] With high vehicular emissions and a projected increase in the number of hot days, Dayton and the broader metropolitan region will likely see more days of unhealthy ozone levels.[xviii] Moreover, a study by the Natural Resources Defense Council found that the larger Cleveland area (no data was available specifically for Dayton) is projected to have approximately 11 more days per summer that exceed the U.S. Environmental Protection Agency's air quality standards.[xix] Changes such as these will have significant ramifications for the health and wellbeing of all Dayton residents, especially the young, elderly, infirm, homeless, and other vulnerable populations.

Changes in Precipitation

The Dayton region has seen a 5.6 percent increase in total annual precipitation from the 1951-1980 average to the 1981-2010 average (Figure 5).[xx] Most of this increase has been during the spring (Figure 6).

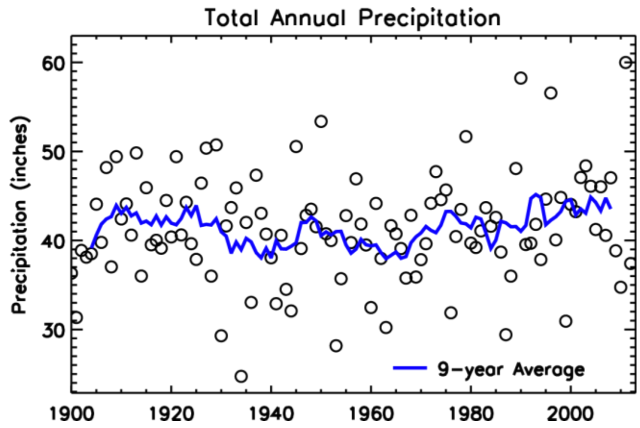

Figure 5: *Total Annual Precipitation from Dayton, 1900-2010. Open circles represent annual totals. The solid blue line is the 9-year running average. Total annual precipitation increased by 5.6% from the 1951-1980 average to the 1981-2010 average. Data from: NCDC.*

The majority of climate models project that precipitation will continue to increase in the Dayton region. Winters, springs, and falls are projected to be wetter, but summers are projected to be up to 5% drier.[xxi] Spring and winter rainfall is projected to increase almost 15 percent over the next several decades and by approximately 30 percent toward the end of the century (under a high greenhouse gas emissions scenario) (Figure 7).[xxii]

Figure 6: Changes in Total Precipitation (%) from 1951-1980 to 1981-2010

Annual	5.7
Winter	2.8
Spring	10.5
Summer	-0.4
Fall	9.7

These changes in precipitation may lead to more flooding, delays in the planting of spring crops, and

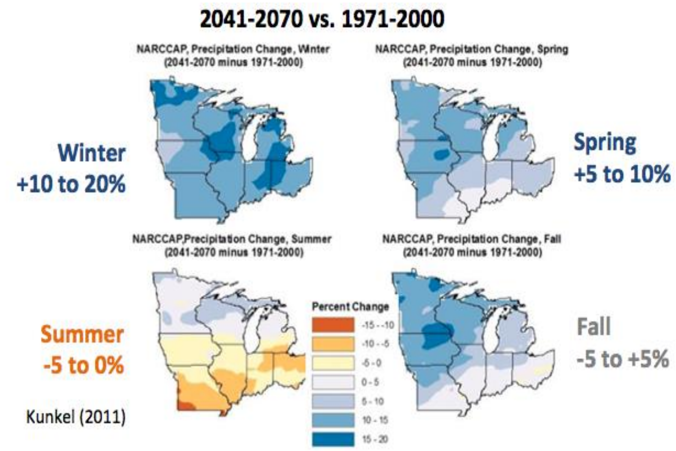

Figure 7: *Projected change in seasonal precipitation in 2041-2070 based on 1971-2000. Annual changes in precipitation is projected to increase by 5-15%. Seasonally, the largest increase in precipitation is projected during the winter (10-20% increase). The largest decrease is projected for summer (-5 to 0% change).*

declining water quality in rivers, streams, and storage reservoirs. In addition, when precipitation falls, it is more likely to come in heavy rainfall events. In fact, in Dayton there was an 88 percent increase in the number of storms exceeding the 1951-1980 99th percentile.[xxiii] Going forward, Day Dayton's future 100-year flood will most likely increase by 10-20% in the coming decades, leading to further implications to economic, social, and natural systems.[xxiv]

The Dayton region, and Ohio as a whole, is also projected to face longer periods without rainfall, which could enhance the risk of short and medium-term drought.[xxv] Projections show that 80 percent of Ohio's counties will face a higher risk of water shortages by mid-century as a result of climate change.[xxvi]

Flooding and Stormwater Management

An increase in the number and intensity of severe storms may affect Dayton's stormwater system and management techniques, as well as the community's overall water quality. An increase in multi-day and heavy rain events across the Midwest has already been observed, leading to a number of stormwater management challenges.[xxvii,xxviii,xxix] With more intense and more frequent severe storms, Dayton could see more localized flooding, especially if the storm water system becomes overwhelmed.

Additionally, an increase in the amount of rain falling in heavy precipitation events can enhance erosion rates and increase the amount of pollutants that run off from impervious surfaces. Impervious surfaces, such as paved parking lots, can also exacerbate stormwater issues by channeling flows into concentrated areas.[xxx]

In regards to surface water, increasing temperatures will likely cause more evaporation and snow melt, thereby reducing Ohio's surface water levels during the next century. Decreased water availability (i.e., lower groundwater recharge, potentially contaminated surface waters) timed with increased demand (due to rising temperatures) could also lead to new or enhanced water conflicts.[xxxi]

Agriculture

Warming winters are already changing the length of the growing season in Dayton (Figure 8). Today's growing season is 1-2 weeks longer than it was at the turn of the century, with an earlier last front in spring and a later date of first frost in winter.[xxxii]

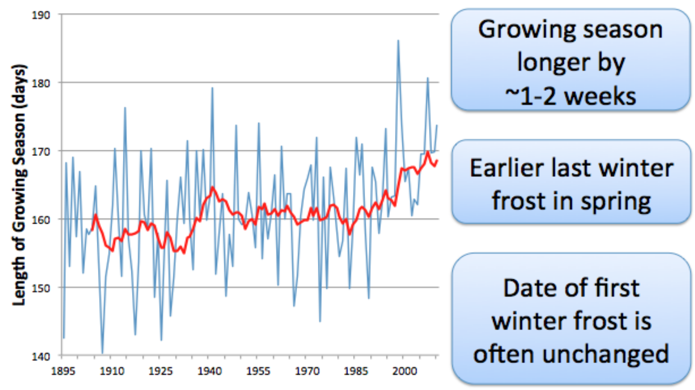

Figure 8: *Change in the length of the growing season in days from 1895 to 2010.*

With projected changes in climate, the growing season will likely be up to six weeks longer than it currently is. This type of change could mean greater economic opportunities through greater crop yields or the potential for additional plantings, but could also lead to an expansion of pests into new ranges (Figure 9).[xxxiii] Additionally, longer growing seasons and increased heat may expose crops and livestock to an increased risk of heat stress, leading to lower livestock productivity and a reduction in crop yields. [xxxiv,xxxv]

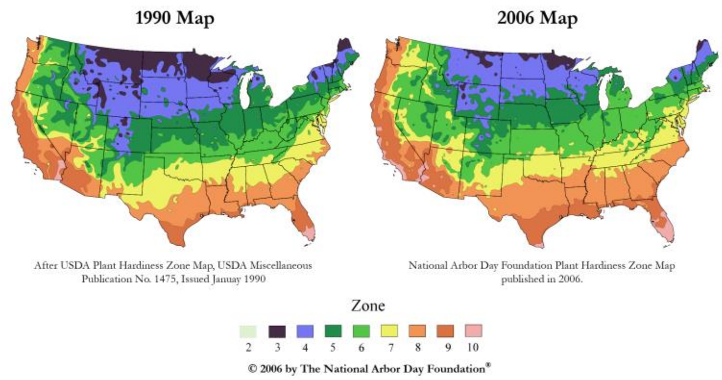

Figure 9: *Plant Hardiness Zones in 1990 and 2006 from the USDA.*

Natural Systems

With increasing temperatures and changes in precipitation, combined with changes in land-use, natural systems could experience significant climate impacts. Increasing temperatures could result in range shifts and altered fish habitat, in many cases enhancing the risk of extinction.[xxxvi] These impacts could also effect recreation and commercial fishing and hunting, visitation to parks and natural spaces, nature-based tourism, and reduce the overall quality of life of local residents.

Increases in temperature and changes in precipitation can also lead to reduced soil moisture, which can, in turn, lead to changes in tree species composition, changes in the geographical distribution of fauna, and a reduction in the overall health of natural systems such as forests. In fact, changes in climate are projected to cause a decline in Ohio's forests of up to 50 percent, which could amount to $8 billion in economic costs and the loss of tens of thousands of jobs.[xxxvii]

Public Health

Climate change poses an array of challenges to public health. Increasing temperatures can lead to short and long-term heat waves that threaten the young, elderly, infirm, homeless, and socially isolated. Increases in precipitation can lead to localized flooding of homes, businesses, transportation routes, and public spaces. [xxxviii] Among other impacts, flooding can affect the ability of emergency service personnel to quickly respond in cases of emergency or lead to the spread of disease vectors and contaminants. [xxxix]

Climate change will also worsen smog and likely increase in the amount of pollen produced by plants. Both of these changes can negatively affect residents, especially those with respiratory problems.[xl]

Transportation

There is a wide array of concerns about the impacts of rising temperatures and more extreme precipitation on transportation infrastructure.[xli,xlii] Although little research has focused directly on the effects of climate change on roadways in the Midwest, damage to paved surfaces, including expansion buckling during extreme heat events, softening of asphalt, and increased stress on bridge joints will become more probable as the number of extremely hot days increases.[xliii] With increasing precipitation and stronger storms, flooding risks to roadways are also a concern. The impacts associated with cold-weather events, such as freeze-thaw damage, remain largely unstudied.

Other Extreme Events

In addition, it is possible that a number of extreme events could be affected by changes in climate. For example, derechos (widespread, severe wind events) and tornadoes are both extreme weather events that may be getting more frequent or intense. While it is unclear how much climate change is or will affect these events, it is important that Dayton be aware of these potential changes and take proactive steps to prepare for the impacts associated with these and other types of extreme events.

Building Resilience

A number of strategies exist to help the City of Dayton build resilience toward existing weather impacts as well as future changes in climate. Strategies that focus on increasing the amount of green infrastructure, encouraging the use of pervious surfaces, on-site stormwater management through rain gardens and bioswales, urban forestry, green and white roofs, energy efficiency, renewable energy, land-use planning, updated zoning policies, the use of reflective pavement, strategies to increase adaptive capacity of residents and businesses, and enhancing community engagement and empowerment are all strategies that can help the City of Dayton and the broader region build resilience towards climate change.

Deciding which strategies make the most sense for Dayton will be a critical next step in the city's climate efforts. Understanding the local community's needs, abilities, interests, and capabilities will be necessary to determine which strategies are most appropriate for Dayton at this time.

References

[i] U.S. Bureau of Economic Analysis (2013). "News Release: GDP by Metropolitan Area, Advance 2011, and Revised 2001-2010," retrieved from http://www.bea.gov/newsreleases/regional/gdp_metro/gdp_metro_newsrelease.htm, June 21, 2013.
[ii] Site Selection Magazine. (2009). "Site Selection Online: Top Metros of 2008," retrieved from http://www.siteselection.com/issues/2009/mar/top-metros/, June 18, 2013
[iii] Dayton Daily News (2010). "Dayton one of the best places for grads to find jobs," retrieved from http://www.daytondailynews.com/news/news/state-regional/dayton-one-of-best-places-for-grads-to-find-jobs/nNFbc/, June 18, 2013
[iv] Xavier University. (2007). Climate Change in Cincinnati: Proceedings of the 2007 Environmental Studies Seminar at Xavier University.
[v] Union of Concerned Scientists. (2009). Confronting Climate Change in the Midwest: Ohio. www.ucsusa.org/mwclimate
[vi] Union of Concerned Scientists. (2011). Great Lakes: Migrating Climates – Ohio. http://www.ucsusa.org/greatlakes/winmigrating/glwinmig_oh.html
[vii] Mastrangelo, G., U. Fedeli, C. Visentin, G. Milan, E. Fadda, and P. Spolaore, 2007: *Pattern and determinants of hospitalization during heat waves: an ecologic study.* BMC Public Health, 7(1): p. 200.
[viii] Semenza, J.C., J.E. McCullough, W.D. Flanders, M.A. McGeehin, and J.R. Lumpkin, 1999: *Excess hospital admissions during the July 1995 heat wave in Chicago.* American journal of preventive medicine, 16(4): p. 269-277.
[ix] O'Neill, M.S. and K.L. Ebi, 2009: *Temperature extremes and health: impacts of climate variability and change in the United States.* Journal of Occupational and Environmental Medicine, 51(1): p. 13-25.
[x] Poumadère, M., C. Mays, S. Le Mer, and R. Blong, 2005: *The 2003 heat wave in France: dangerous climate change here and now.* Risk Analysis, 25(6): p. 1483-1494
[xi] Basu, R. and J.M. Samet, 2002: *Relation between Elevated Ambient Temperature and Mortality: A Review of the Epidemiologic Evidence.* Epidemiologic Reviews, 24(2): p. 190-202.
[xii] Harlan, S.L., A.J. Brazel, L. Prashad, W.L. Stefanov, and L. Larsen, 2006: *Neighborhood microclimates and vulnerability to heat stress.* Social Science & Medicine, 63(11): p. 2847-2863.
[xiii] Buechley, R.W., J.V. Bruggen, and L.E. Truppi, 1972: *Heat Island or Death Island?* Environ Research, 52.
[xiv] Curriero, F.C., K.S. Heiner, J.M. Samet, S.L. Zeger, L. Strug, and J.A. Patz, 2002: *Temperature and mortality in 11 cities of the eastern United States.* American Journal of Epidemiology, 155(1): p. 80-87.
[xv] Economic Profile Systems – Human Dimensions Toolkit. (2013). A Profile of Demographics: State of Ohio versus Dayton, Ohio.
[xvi] Union of Concerned Scientists (UCS), 2012: *Heat in the Heartland: 60 Years of Warming in the Midwest.* http://www.ucsusa.org/assets/documents/global_warming/Heat-in-the-Heartland-Full-Report.pdf.
[xvii] Luber, G. and M. McGeehin, 2008: *Climate change and extreme heat events.* American journal of preventive medicine, 35(5): p. 429-435.
[xviii] Union of Concerned Scientists (UCS), 2012: *Heat in the Heartland: 60 Years of Warming in the Midwest.* http://www.ucsusa.org/assets/documents/global_warming/Heat-in-the-Heartland-Full-Report.pdf.
[xix] Natural Resources Defense Council. 2007. Heat Advisory: How Global Warming Causes More Bad Air Days
[xx] Great Lakes Integrated Sciences and Assessments (GLISA) Center, 2013: *Historical Climatology: Dayton, Ohio.*
[xxi] Union of Concerned Scientists. 2009. Confronting Climate Change in the Midwest: Ohio. www.ucsusa.org/mwclimate
[xxii] ibid
[xxiii] Great Lakes Integrated Sciences and Assessments (GLISA) Center, 2013: *Dayton Climate Workshop Presentation by Dan Brown.*
[xxiv] National Climate Assessment. 2013. Draft Chapter of the Midwest Chapter of the National Climate Assessment
[xxv] Natural Resources Defense Council. 2010. Climate Change, Water, and Risk
[xxvi] Wu, Shuang-Ye. 2010. Potential impact of climate change on flooding in the Upper Great Miami River Watershed, Ohio, USA: a simulation-based approach, Hydrological Sciences Journal, 55: 8, 1251 — 1263
[xxvii] Changnon, S.A. and N.E. Westcott, 2002: Heavy Rainstorms in Chicago: Increasing Frequency, Altered Impacts, and Future Implications. JAWRA Journal of the American Water Resources Association, 38(5): p. 1467-1475.
[xxviii] Changnon, S.A., K.E. Kunkel, and K. Andsager, 2001: *Causes for Record High Flood Losses in the Central United States.* Water International, 26(2): p. 223-230.
[xxix] Wuebbles, D.J. and K. Hayhoe, Year: *Climate change and Chicago: projections and potential impacts*. in *20th Conference on Climate Variability and Change*. 2008.
[xxx] International Joint Commission, 2009: *The Impact of Urban Areas on Great Lakes Water Quality, 2009.*
[xxxi] National Association of State Legislatures. 2008. Climate Change and the Economy: Ohio_Assessing the Costs of Climate Change.
[xxxii] *Based on data from the National Climatic Data Center for the cooperative observer network and updated from Kunkel et al. (2004)*
[xxxiii] Union of Concerned Scientists. 2009. Confronting Climate Change in the Midwest: Ohio. www.ucsusa.org/mwclimate
[xxxiv] ibid
[xxxv] Natural Resources Defense Council. 2013. Climate Change Health Impacts in Ohio. http://www.nrdc.org/health/climate/oh.asp
[xxxvi] Union of Concerned Scientists. 2009. Confronting Climate Change in the Midwest: Ohio. www.ucsusa.org/mwclimate
[xxxvii] National Association of State Legislatures. 2008. Climate Change and the Economy: Ohio_Assessing the Costs of Climate Change.
[xxxviii] Natural Resources Defense Council. 2013. Climate Change Health Impacts in Ohio. http://www.nrdc.org/health/climate/oh.asp
[xxxix] ibid
[xl] ibid
[xli] Transportation Research Board, 2011: *Adapting transportation to the impacts of climate change.* Special Task Force on Climate Change and Energy. Transportation Research Circular E-C152.
[xlii] ibid
[xliii] Posey, J., 2012: *Climate Change Impacts on Transportation in the Midwest*. In: *U.S. National Climate Assessment Midwest Technical Input Report*. J.A. Winkler, J. Andresen, J. Hatfield, D. Bidwell, and D. Brown, coordinators. Great Lakes Integrated Sciences and Assessments (GLISA) Center