Sustainable Jersey Climate Change Adaptation Task Force (CATF)

New Jersey Climate Change Trends and Projections Summary

This document is intended to provide New Jersey communities with a clear picture of the observed trends and projected future changes in the climate system. It also provides an introductory set of planning resources for adapting to climate change impacts.

Climatic changes such as extreme heat, severe storms, flooding, drought, and sea level rise pose real threats to New Jersey's built environment and natural environment. Observations and modeling suggest that documented changes, especially in recent decades, have been driven in large part by human influences on the climate system. But regardless of the causes of climate change, or any policy debates about the solutions, communities must begin preparing for the expected changes, some of which will be unavoidable.

A fundamental starting point for identifying vulnerabilities and developing action plans to adapt to climate change is to understand the most likely changes in local climate based on current trends and projections of temperature, precipitation and storm patterns. Understanding these changes will help New Jersey municipalities begin to identify the specific risks that climate change poses to their community and consider planning to prepare for such change.

This document is divided into three sections. The first section**,** *Observed Climate Changes and Trends,* is a summary of observed changes in climate in New Jersey over roughly the past 100 years. This section illustrates how past trends verify that the climate in New Jersey is already changing. The second section, *Climate Change Projections,* summarizes how climate in the Northeast U.S. will likely change in the future based on averages of current climate science modeling. This section illustrates the potential climate changes that could impact the Northeast U.S. under an average GHG emissions scenario. With an understanding of how the climate in New Jersey is already changing and how it is projected to continue to change in the future, municipalities can begin the process of developing action plans and strategies that address the specific local impacts that climate change poses on their community. The third and last section on *Need for Climate Change Adaptation Planning* provides information and list of resources on the climate adaptation planning process.

Observed Climate Changes and Historical Trends

The following is a summary of observed changes or averages, in the basic elements of the climate such as temperature, precipitation, storms and extreme weather events in the New Jersey region over roughly the past 100 years. The 100 year time frame generally marks the start of consistent record keeping for these climatic elements. These observations reveal a number of statistically significant trends in the climatological system for New Jersey. This summary is based on recorded climate data archived by the Office of New Jersey State Climatologist (ONJSC) and other institutions.

In reading these trends, please keep in mind that these are historical trends. The next section explains the projection of what is anticipated in the future. Also note that for certain rare events, like droughts or extreme precipitation, there is not a statistically large enough sample to show a clear trend. However, this does not mean that no problem exists. Therefore, the climate projections in the next section will help communities identify and address the impacts in the future.

Temperature: Temperatures in the Northeast U.S. have increased 1.5 degrees Fahrenheit (°F) on average since 1900. Most of this warming has occurred since 1970. The State of New Jersey, for example, has observed an increase in average annual temperatures of 1.2 ^{0}F between the period of 1971-2000 and the most recent decade of 2001-2010 (ONJSC, 2011). Winter temperatures across the Northeast have been rising even faster than annual average temperatures, up 4 °F since 1970.[1]

***Heat Waves*:** In New Jersey, the total number of days over 90 °F has increased by roughly 36 percent since 1949. On average, based on historical data from 16 weather station locations spread across the State, days over 90 °F have increased from about 17 a year to 23, although there is considerable range between north and south, coastal and inland, and urban and rural parts of New Jersey.[2]

- **Precipitation:** Both northern and southern New Jersey have become wetter over the past century. Northern New Jersey's 1971-2000 precipitation average was over 5" (12%) greater than the average from 1895-1970. Southern New Jersey became 2" (5%) wetter late in the 20th century. Autumn (Sept-Nov) has seen the greatest increases, with summer having the least in both northern and southern New Jersey.[3]

Extreme Precipitation: Extreme precipitation, defined as precipitation above 1, 2 or 4 inches at daily timescales, is highly variable both spatially and temporally. Year to year variation in extreme precipitation events is large, and long time series data are required to observe statistically meaningful trends. In other words, there is a relatively large "burden of proof" required to distinguish a meaningful trend from random variability. According to data gathered by the New York City Panel on Climate Change, there has been a small, but not statistically significant trend, towards more extreme precipitation events in the region during the last three decades.

Drought: New Jersey has experienced one severe water-supply drought (2001-2002) and three minor ones (2005, 2006 and 2010) in the last decade.[4] Even so, there is no significant long-term trend visible in the frequency or severity of droughts in New Jersey, going as far back as 1895.[5] New Jersey has a comprehensive drought monitoring system which allows assessment of drought conditions periodically.

- **Sea Level Rise:** Globally, sea level rose roughly 8 inches over the past 100 years. Along the coast of New Jersey, sea level has risen an additional 4 to 8 inches during the past 100 years due to subsidence (a sinking of the ground surface due to natural geological processes and/or human influences like removal of groundwater for human use) in the mid-Atlantic region. Total relative sea level rise (the combination of rising seas and subsidence) in New Jersey over the past 100 years is therefore approximately 12 to 16 inches.[6]

- ***Hurricanes and Coastal Storms*:**
  There is no statistically significant trend in the number of land falling hurricanes on the east and gulf coast areas.[7] However, there is some evidence that warming of the oceans has led to more intense hurricanes since 1975.[8]

  Storm surge is a rise in coastal water levels associated with a low pressure weather system. In New Jersey, storm surges are most often associated with nor'easters and tropical cyclones (hurricanes). Storm surges are caused primarily by high winds pushing on the ocean's surface. The wind causes the water to pile up higher than the ordinary sea level, leading to flooding*, inundation and erosion.

While coastal New Jersey has experienced numerous storm surge events of varying levels of intensity over the past century, there is currently no discernable trend in the frequency or severity of storm surges. Since there is a high degree of variability in the frequency and intensity of nor'easters and hurricanes and their associated storm surges from year to year, they need to be tracked over long time scales before a statistically significant trend can be documented.

Climate Change Projections

- The following is a summary of climate change projections for the Northeast U.S. and New Jersey based on averages of current climate science modeling. This section illustrates the potential climate changes that could affect the Northeast U.S. under an average GHG emissions scenario. Such an average could be considered as well considered "best guess" of the scientific community on what the future holds. For planning purposes, this should also be considered as a scenario to be taken seriously and to form the basis for considering making preparations for the future (See Appendix for brief background information on methodology for climate change projections).

- **Temperature:** By the 2020s, the mean annual temperature in New Jersey will have increased 1.5 to 3 °F above the statewide baseline (1971-2000) average of 52.7 °F degrees. By the 2050s it will be up 3 to 5 °F, and by the 2080s it will be 4 to 7.5 °F warmer than today.[9] The recorded 2001-2010 average already shows up to a 1.2° F degree (53.9 °F) increase relative to the baseline[10] These projections are based on the averages from 16 global climate models (GCMs) and 3 emissions scenarios and represent the middle 67% of values from model-based probabilities.

* Inland (fresh water) flooding is also important to consider. While flooding is not a pure climate element, it is a critical response to excessive rainfall, rapid snow melt, ice jams or combinations thereof, and therefore strongly related to weather/climate conditions (particularly major river flooding). Flooding, particularly flash flooding, can be amplified by human development and the resultant increase in impervious surfaces or fields/farmland. Further editions of this primer will include data on the most recent major flood events in New Jersey, which is currently being analyzed.

Geographically, these estimates are centered on the Newark, NJ region. While there will likely be little difference in the average annual temperature increase across the State, southerly latitudes and coastal areas may experience slightly less warming (~0.5 °F) than northerly and inland regions of the State by the 2080s.[11] Differences in baseline temperature across the State will continue to have a much greater range than the range in overall average increases in temperature.

***Extreme Heat*:** Extreme heat events are expected to increase in both intensity and duration in the region. Currently, the area experiences on average two heat waves a year (where temperatures exceed 90^0F)of about four days in duration. By the 2020s, it is projected to be three to four events of four to five days; by the 2050s, four to six events of about five days; and by the 2080s, summers could have five to eight heat waves of five to seven days each on average. Annual days over 90 °F will rise from an average of 14 in 2000 to 23 to 29 by the 2020s, 29 to 45 by the 2050s, and 37 to 64 by the 2080s.[12]

- **Precipitation:** Average annual precipitation is expected to increase in the region by up to 5% by the 2020s and up to 10% by the 2050s.[13] Most of this additional precipitation will come in the winter, where a 20-30% increase in precipitation (mostly rain) is projected by the late century.[14]

***Extreme Precipitation*:** While models suggest that the percentage increase in annual precipitation across the mid-Atlantic region is expected to be on the order of 10% or less by mid-century, a perhaps more significant concern is that this precipitation is more likely to fall during extreme events causing inland flooding. This projection is consistent both with theory and observed trends nationally over the 20th century.

Developing quantitative projections for these relatively brief and highly variable events (i.e., downpours) requires a number of statistical downscaling techniques to interpret larger scale (and more reliable) global and regional models at the state and local level. Accordingly, there is some uncertainty in these types of projections. In general, climate models tend to be more reliable when examining annual averages as opposed to the frequency of specific extreme events. Analyses performed for New York City indicate a 10 to 25% increase in the frequency of intense precipitation events by the 2080s.[15] These projections would be broadly applicable on average across most of New Jersey.

Drought: Even though overall precipitation is likely to increase under climate change, most of this increase is expected to occur in the winter months. Summer precipitation is not forecasted to increase much, if at all, and is not likely to be evenly distributed throughout the season. This fact, combined with greater evapotranspiration due to additional heat, is likely to lead to more frequent occurrences of short-term soil moisture droughts across the Northeast. This will create greater stresses on agriculture. However, given the likelihood of heavier cool-season precipitation, current modeling indicates that water-supply droughts will be no more or less frequent or severe than under existing climate conditions.[16]

- **Sea Level Rise:** The 2007 Intergovernmental Panel on Climate Change (IPCC) assessment projected that mean sea level would rise two to five inches by 2020, seven to 12 inches by 2050, and 12 to 23 inches by the end of the century. However, these projections do not take into consideration melting of the Greenland and Antarctic Ice Sheets, which will contribute substantially to sea level rise.[17] The Greenland ice sheet, in particular, has been experiencing record amounts of surface melting in recent years. From a state of "near balance" in the 1990s, the ice sheet is now losing over 300 gigatons (billion tons) of ice a year over the past decade, while the East Antarctic ice sheet is losing over 150 gigatons per year [18] By incorporating ice sheet melting patterns, sea level is projected to rise from 0.5 to 1.8 meters (20 to 71 inches) by 2100 over 1990 levels.[19] . The upper limit for the end of the 20th century is constrained by melting ice to be less than 2 m (79 inches).[20] Because we are currently tracking on an 80 cm (31 inch) global rise by 2100 [21] New Jersey should plan for at least 1 m (39 inches) of rise, including the effects of subsidence, by the end of the 21st century.

  New IPCC estimates of sea level rise, which are expected to be published in 2014, will incorporate the most recent scientific research on the rate of ice sheet melting and its impact on future sea level rise. The Greenland and East Antarctic ice sheets contain enough water to raise global sea level by approximately 23 and 20 feet, respectively.[22]

- ***Hurricanes and Coastal Storms***: Many models suggest an increase in intense hurricanes and thus extreme winds, although there is still uncertainty on this subject. At this point, it can only be stated that more intense hurricanes may become more likely than not. It is not possible to say at this point in time, even qualitatively, whether or not hurricanes will become more frequent.[23]

Sea level rise combined with potential changes in the frequency and severity of hurricanes and nor'easters could lead to both higher and more frequent coastal flooding. Therefore, coastal flooding that qualifies as a 100-year flood today will happen on average once every 65 to 80 years by the 2020s, once every 35 to 55 years by the 2050s, and once every 15 to 35 years by the 2080s.[24]

- **Ice Storms and Snowfall:** There is still considerable uncertainty and a lack of quantitative projections for the frequency and intensity of freezing rain and ice storm events in New Jersey.

  Snowfall events are likely to become less frequent and the snow season will decrease in length. Possible changes in the intensity of snowfall per storm are highly uncertain.[25]

Need for Climate Change Adaptation Planning

Understanding existing and projected changes in the climate system is a fundamental starting point for local communities to develop plans and take actions to address how those changes impact their residents, resources and infrastructure. Climatic changes such as extreme heat, severe storms, flooding, drought, and sea level rise pose threats to a wide variety of sectors including the built environment (e.g., roads, buildings), water resources, agriculture, forests, wildlife habitat, outdoor recreation, human health, and others. Most of these impacts can be addressed through preventive action. Thinking ahead about the impacts of climate change on these sectors is essential for communities to reduce risks and lower the long-term costs of damage resulting from climate change.

It is important to recognize that built, natural and human systems already experience wide fluctuations in weather events and climate conditions (flooding and heat waves are not new), and most of these systems are equipped to deal with fluctuations within a certain range. This is characterized as a system's "adaptive capacity". Nature has evolved to tolerate expected fluctuations based on the historical patterns. Human systems are engineered to tolerate specific expected conditions. When the climate changes, systems and sectors can be stressed beyond their current adaptive capacity. Identifying where systems reach these breaking points, such as when an increase in the 1%-annual-chance flood height tops a dike, berm or seawall designed to withstand the existing 1%-

annual-chance flood level, is a key step in identifying a community's vulnerabiltiy to climate change.

Conducting an adaptation planning process will enable local governments to understand the adaptive capacity of their local systems, identify ways to address emerging risks and vulnerabilities from predicted changes in climate, and prioritize a plan of action to increase resiliency to climate-related impacts. The most successful adaptation programs include the following elements:

1. An effort to increase public and stakeholder awareness of climate change impacts and possible solutions. *In order to carry out an adaptation plan, it is crucial that local governments identify key stakeholders in their community that will be necessary partners in implementation and educate them on the impacts and risks. It is also important to involve local citizens as the plan evolves and more information becomes available.*

2. A risk and vulnerability assessment that first highlights known potential threats and past climate related events (i.e. local historic climate trends and the existing adaptive capacity of local resources). These vulnerabilities have the potential to be further stressed by climate change. Once this is known, local governments can identify how the adaptive capacities of these local systems are vulnerable to the impacts of climate change.

3. An identification of options for increasing resiliency in all systems and sectors to locally predicted climate changes.

4. Developing and implementing an adaptation strategy that reduces a community's exposure to threats, and develops response plans to quickly recover.

While adaptation planning can be conducted as a "stand-alone" project initially, ultimately, to be successful, implementation needs be mainstreamed into existing planning efforts and normal operation procedures. Smart and integrated planning will ensure that governments and communities identify those systems most vulnerable to climate change impacts, while laying the groundwork for actions to reduce the risk to human life, ecosystems, infrastructure and the economy.

Many resources already exist to assist local communities with adaptation planning. The following is a brief list of useful links:

- International Council on Local Environmental Initiatives (ICLEI)'s *Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments.* http://www.iclei.org/fileadmin/user_upload/documents/Global/Progams/CCP/Adaptation/ICLEI-Guidebook-Adaptation.pdf
- U.S. Climate Change Science Program (CCSP). http://www.globalchange.gov/what-we-do/adaptation-science
- Pew Center on Global Climate Change, *Climate Change 101: Adaptation.* http://www.pewclimate.org/climate-change-101/adaptation
- State and City Adaptation planning reports
  - Pennsylvania Climate Change Adaptation Planning Report: Risks and Practical Recommendations. http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-82988/7000-RE-DEP4303%20combined%20report.pdf
  - Climate Change Adaptation in New York City: Building a Risk Management Response. http://www.nyas.org/publications/annals/Detail.aspx?cid=ab9d0f9f-1cb1-4f21-b0c8-7607daa5dfcc
  - Pew Center on Global Climate Change, *Adaptation Planning – What U.S. States and Localities are Doing.* http://www.pewclimate.org/docUploads/state-adapation-planning-august-2009.pdf

Appendix: Note on Methodology for Climate Change Projections

To develop this summary, the Sustainable Jersey Climate Adaptation Task Force researched a number of reputable sources, including the United States Global Change Research Program, the Northeast Climate Impacts Assessment (NECIA), the New York City Panel on Climate Change, the Office of the New Jersey State Climatologist and others. A list of these sources is provided at the end of this summary.

To model future climate changes, scientists must address two key uncertainties: uncertainties in future greenhouse gas emissions and uncertainties in how the climate will respond to these emissions. To forecast emission levels, the Intergovernmental Panel on Climate Change (IPCC) developed a set of possible futures, or scenarios, based on a variety of variables including population growth, economic growth, energy use, and other societal choices. Scenarios based on "business-as-usual" trends forecast rapid growth in emission levels. Lower-emission scenarios assume a relatively rapid shift to less fossil fuel-intensive industries, more resource-efficient technologies, and policies to encourage conservation. Often, a high, middle and low emissions scenario is used to develop a range of climate change impact projections.

To address the second uncertainty, researchers use Global Climate Models (GCMs) to project how the climate will respond to varying levels of emissions. Once an emissions scenario is chosen, GCMs produce projections for climate variables such as temperature, seasonal precipitation and extreme weather events. Projections are typically given in ranges, e.g., 1 to 2.5° F warming. Such ranges capture the level of uncertainty in climate modeling. Wider output ranges reflect greater levels of uncertainty.

The projected changes summarized in the second section above, *Climate Change Projections*, were mostly developed by averaging high, middle and low emissions scenarios. Likewise, projections are based on a central range of model outputs averaged across multiple GCMs. Accordingly, the projections summarized here focus on the “middle of the middle” of climate change projections. Future scenarios in which changes in temperature, precipitation, etc. are much higher or much lower are certainly possible, but the projections described below represent the most likely, or most probable, range of outcomes based on current data and modeling. Where warranted, more extreme possibilities and ranges are noted for planning purposes.

For more detailed information on uncertainties associated with emissions scenarios and GCMs, we recommend consulting the New York City Panel on Climate Change’s *Climate Risk Information* report and the Northeast Climate Impacts Assessment (see Sources for links).

Sources and Notes

[1] Northeast Climate Impacts Assessment (NECIA) http://www.climatechoices.org/assets/documents/climatechoices/confronting-climate-change-in-the-u-s-northeast.pdf

[2] National Climatic Data Center (NCDC). http://www.ncdc.noaa.gov/oa/ncdc.html

[3] Office of New Jersey State Climatologist (ONJSC). http://climate.rutgers.edu/stateclim/

[4] NJDEP Drought Records. NJ declared a drought emergency (for water-supply) for almost all of 2002. In 2005, 2006 and 2010, NJ declared a drought watch (for water-supply) for less than 2 months each year.

[5] National Drought Mitigation Center (NDMC). http://drought.unl.edu/whatis/palmer/midatlan.gif

[6] U.S. Climate Change Science Program (USCCSP) Report. http://downloads.climatescience.gov/sap/usp/usp-prd-all09.pdf

[7] USCCSP Report.

[8] NECIA.

[9] New York City Panel on Climate Change (NPCC) http://www.nyc.gov/html/om/pdf/2009/NPCC_CRI.pdf

[10] ONJSC. http://climate.rutgers.edu/stateclim/

[11] NPCC.

[12] NPCC.

[13] NPCC.

[14] NECIA.

[15] NPCC.

[16] NPCC & ONJSC.

[17] NPCC.

[18] Rignot *et al.* 2011. 'Acceleration of the contribution of the Greenland and Antarctic ice sheets to sea level rise", *Geophysical Research Letters,* vol. 38, L05503.

[19] Rahmstorf, S. 2007. "A Semi-Empirical Approach to Projecting Future Sea-Level Rise", *Science,* vol. 315 no. 5810 pp. 363-370. http://www.sciencemag.org/content/315/5810/368.short

[20] Peffer *et al*. 2008. "Kinematic constraints on glacier contributions to 21st century sea level rise", Science, vol. 321.

[21] Rahmstorf *et al*. 2007. "Recent climate observations compared to projections", *Science*, vol. 316.

[22] USCCP Report.

[23] NPCC.

[24] NPCC.

[25] NPCC.