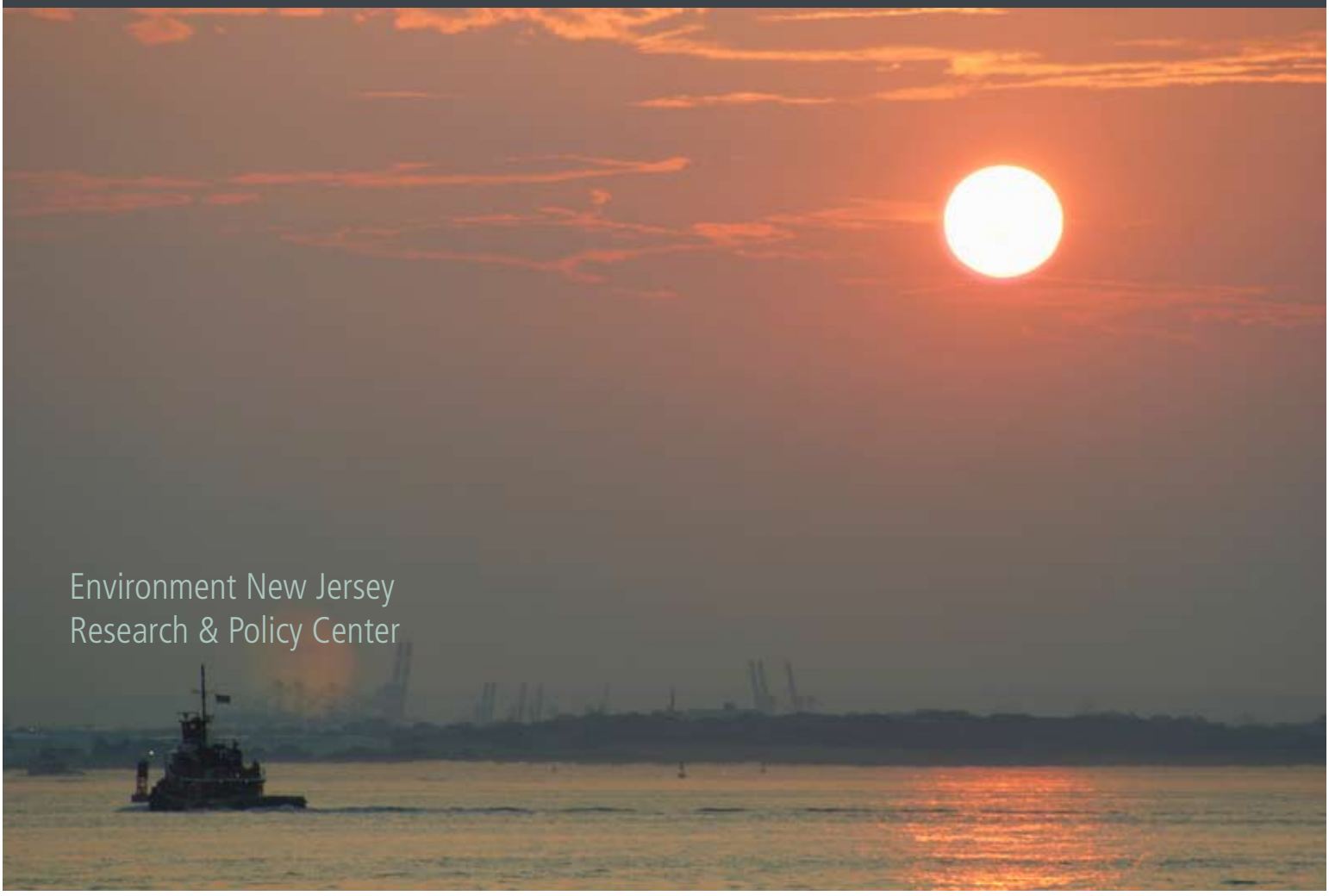
An Unfamiliar State

Local Impacts of Global Warming in New Jersey



Environment New Jersey
Research & Policy Center

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Local Impacts of Global Warming in New Jersey

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Environment New Jersey Research & Policy Center is a 501(c)(3) organization. We are dedicated to protecting New Jersey's air, water and open spaces. We investigate problems, craft solutions, educate the public and decision makers, and help New Jerseyans make their voices heard in local, state and national debates over the quality of our environment and our lives.

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Photo: William Picard

Executive Summary

Global warming poses a serious threat to the future of New Jersey's environment, economy, and the health and welfare of its citizens.

Global warming will impact every corner of the state. If global warming pollution across the world continues to rise, New Jersey will be a different place in 100 years, with an altered coastline, greater extremes of rainfall and drought, higher levels of smog in parts of the state, and shifts in the plant and animal species that call New Jersey home.

If we act now, there is still time to prevent many of the worst impacts of global warming. New Jersey must do its share to reduce global warming pollution and set an example for other states and the nation to follow.

Scientists foresee increased warming over the next century and beyond, with consequences for the environment, the economy and human health.

- The Intergovernmental Panel on Climate Change (IPCC), the world's leading authority on the science of global warming, projects that world average temperatures will increase by another 3 to 7° F above late 20th century levels by the end of this century, depending on future emissions of global warming pollutants. At the highest emission scenario evaluated by the IPCC, estimates of warming range between 4.3 and 11.5° F.
- World average sea level could be expected to rise by another 11 to 17 inches over the next century, with the magnitude dependent on future emissions. At the highest emission scenario evaluated, sea level rise could be between 10 and 23 inches. These estimates do not include the potential for accelerated breakup of the Greenland or Antarctic ice sheets, which would cause a more dramatic rise in sea level.
- Snow and ice cover will continue to contract, heat waves will become more frequent and severe, and hurricanes will likely become stronger.

If unchecked, global warming will affect every corner of New Jersey in the coming century:

- *The Shore: Inundated boardwalks, receding*

beaches. A global warming-induced sea-level rise of 16 to 31 inches (within the range of what scientists forecast for New Jersey) could inundate low-lying lands along the Shore, including much of the city of Wildwood, turning North Wildwood into an island. At the same time, sea level rise could cause Cape May Beach and other shore beaches to erode between 160 and 500 feet.

- *New York City Metro Area*: *Vital infrastructure under threat*. Sea-level rise puts New Jersey's vital transportation links with New York City and the world at greater threat of flooding during severe storms. Higher seas could put the Holland Tunnel at risk of flooding with up to 3 feet of water every five years. Newark Airport, the Lincoln Tunnel and key highway links would also be increasingly vulnerable to flooding. Scientists estimate that increased flooding could triple the amount of flood damage faced by the region in an average year, with a maximum one-time loss of $250 billion possible from a direct impact by a Category 4 hurricane.
- *Urban New Jersey: More heat-related deaths.* By 2050, the number of days in Newark with high temperatures above 90 degrees Fahrenheit could more than quadruple, rising to 60 out of 92 days. As a result, the number of heat-related deaths per summer in Newark could rise more than five-fold.
- *Suburban New Jersey: Worsened smog pollution.* More frequent heat waves will increase the levels of smog pollution, especially in suburban counties. The number of smog-related deaths, a benchmark for more widespread damage to public health, could increase by more than 6 percent in Mercer, Somerset, Hunterdon and Ocean counties.
- *Highlands and Pinelands Agriculture: Longer growing seasons, more threats to crop health.* Corn farmers in Warren County and blueberry farmers in the Pinelands could benefit from longer growing seasons, but their crops will face greater heat stress, more variable water supplies and increased pest populations.
- *The Delaware Valley: More dangerous floods.* Global warming could cause more extreme weather events, much like the four huge rainstorms that struck the Delaware River Valley between July 2004 and June 2006. These four storms damaged or destroyed more than 51 dams, flooded thousands of homes and caused more than $150 million in property damage. The large northeaster that hit New Jersey in April 2007 also provided a glimpse of the impact of extreme weather, submerging Manville under Raritan River floodwaters for three days and forcing 3,000 people to evacuate from their homes.
- *Camden: Water supply at risk.* As sea level rise pushes the mixing zone between salty and fresh water higher up the Delaware River, saltwater could invade the aquifers where Camden gets its drinking water.
- *Delaware Bay: Reduced numbers of migratory birds*. Rising temperatures could harm migratory bird species like the Red Knot, which is famous for its annual migrations from Chile to the Arctic. Every year, Red Knots and other migratory birds stop in Delaware Bay just in time for Horseshoe Crab spawning, feasting on crab eggs to refuel. Changing temperatures could provoke earlier migration or altered timing of spawning, reducing the availability of food and accelerating the decline of the species.

- *The Pinelands: More attacks from the Southern Pine Beetle.* In 2001 the Southern Pine Beetle re-entered New Jersey after an absence of more than 60 years. The beetle has now infested more than 2,000 acres of forest, including areas in the New Jersey Pinelands. Warmer temperatures will help the beetle spread further north, likely contributing to a shift in the types of trees that will grow in the Pinelands.

There is still time to prevent the worst impacts of global warming, but we must act quickly.

To prevent the worst impacts of global warming, New Jersey and the rest of the United States must stabilize global warming emissions at or below today's levels by the end of the decade and reduce emissions by at least 15 to 20 percent by 2020 and at least 80 percent by 2050. To accomplish these goals, New Jersey should:

- **Establish a statewide cap on global warming pollution.** The cap should reduce New Jersey's total global warming pollution by 20 percent by 2020 and 80 percent by 2050. It should cover all sectors of New Jersey's economy and require legally binding emission reductions.
- **Create a long-term global warming action plan.** The action plan should map out how New Jersey plans to reach an 80 percent reduction in global warming emissions by 2050. It should include policies prohibiting the construction of any new coal-fired power plants; requiring all electricity imported to New Jersey from the regional electricity grid to meet state emissions standards; efficiency measures such as energy efficiency standards for public utilities, combined heat and power and demand response initiatives; doubling funding for New Jersey's Clean Energy Program; deploying wind power off New Jersey's coast; requiring developers to provide solar energy as an option for all new homeowners; increasing transit and rail freight options; reducing vehicle miles traveled; restraining urban and exurban sprawl; and reducing global warming emissions from cars, trucks and other vehicles.
- **Call on federal leaders to implement policies to reduce global warming pollution.** New Jersey should ask leaders in Congress and the White House to commit to reducing global warming emissions 20 percent by 2020 and 80 percent by 2050. Important steps toward this goal include increasing federal automobile fuel efficiency standards to 40 miles per gallon within 10 years and creating a federal renewable energy standard requiring 20 percent of the nation's electricity to come from clean, renewable sources of energy like wind and solar power by 2020.

Introduction

For those who saw Al Gore's movie, "An Inconvenient Truth," global warming might conjure up images of massive hurricanes, melting glaciers, or stranded polar bears.

In New Jersey, the impacts of global warming may be less cinematic, but they are no less central to the future of our way of life.

Many New Jerseyans are keenly aware of the threat global warming-induced sea-level rise poses to the Jersey Shore and the Meadowlands. Indeed, by the end of the century, these icons of New Jersey life and vital natural resources could be irrevocably altered by rising seas and more severe storms.

But global warming will also have impacts in other corners of New Jersey. People living along rivers like the Delaware and the Raritan could experience more episodes of severe and destructive flooding. City-dwellers will face hotter summers; suburbanites will experience more health-threatening smog; and farmers will face new headaches from drought and pests. Unique natural areas like the Pinelands and unique species like the migratory birds that frequent Delaware Bay will be threatened. And New Jersey's vast public infrastructure – from our highways, tunnels and ports to our drinking water supplies – could face new challenges.

New Jersey has the tools to reduce the threat posed by global warming to our state's future. Scientists tell us that we still have time to prevent the worst impacts of global warming – if we act now to reduce our global warming pollution. New Jersey has begun to act, by adopting standards to reduce global warming pollution from cars, implementing measures to expand the production of renewable energy, and bolstering efforts to improve the energy efficiency of New Jersey's economy.

Much more remains to be done, however. The next step is to lay out a specific framework to tackle global warming on an economy-wide scale. By adopting a mandatory limit on global warming pollution from the New Jersey economy – coupled with an plan for how to meet that limit over the next 50 years – New Jersey can take the lead in reducing its own emissions and show the way forward for other states and the nation as a whole.

Understanding Global Warming

Primarily through the burning of fossil fuels, humans have changed the composition of the atmosphere. As a result, the atmosphere is trapping more of the heat from the sun's rays, increasing the average temperature of the earth's surface.

The signs of global warming are now apparent in New Jersey and across the globe.

Global Warming is Happening Now

Worldwide, average temperatures have risen by more than 1.4° F in the past century.[1] Since 1975, temperatures have been increasing at a rate of about 0.4°F (0.2°C) per decade.[2] Of the 12 warmest years (in terms of land and sea temperatures) since record-keeping began in 1850, 11 have occurred since 1995.[3]

Temperatures across the U.S. are following the same trend. 2006 was the warmest year to date in the lower 48 states.[4]

New Jersey's climate is no exception:

- 2006 was the second-warmest year ever recorded in New Jersey.[5]
- The mean temperature in New Jersey over the 2001-2006 period was 2.1°F (1.2°C) warmer than the mean temperature from 1895 to 1970, according to an analysis by the Office of the New Jersey State Climatologist.[6] (See Figure 1.)
- Of the 12 warmest years in New Jersey since record-keeping began, four have occurred since 2001 and eight have occurred since 1990.[7]

Human Activity is Causing Global Warming

According to the consensus view of the world scientific community, human activity is the primary cause of global warming.

Global warming is caused by human exacerbation of the greenhouse effect. The greenhouse effect is a natural phenomenon in which gases in the earth's atmosphere, including water vapor and carbon dioxide, absorb infrared radiation emitted from the earth's surface and subsequently heat the atmosphere and warm the surface—much like a blanket wrapped around the earth.

Figure 1: Annual Mean Temperatures in New Jersey[8]

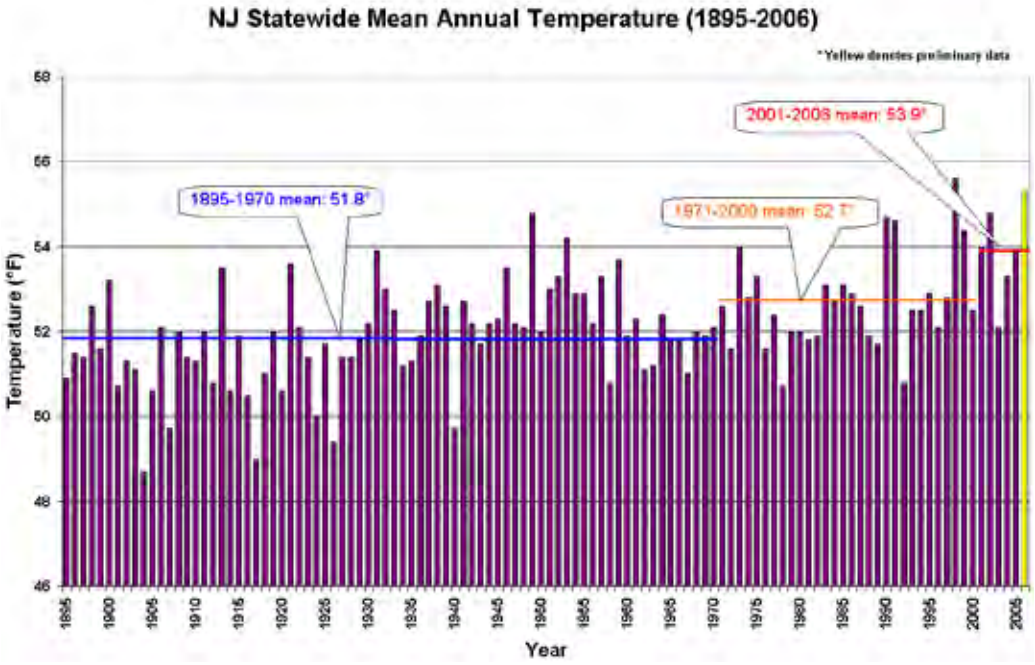
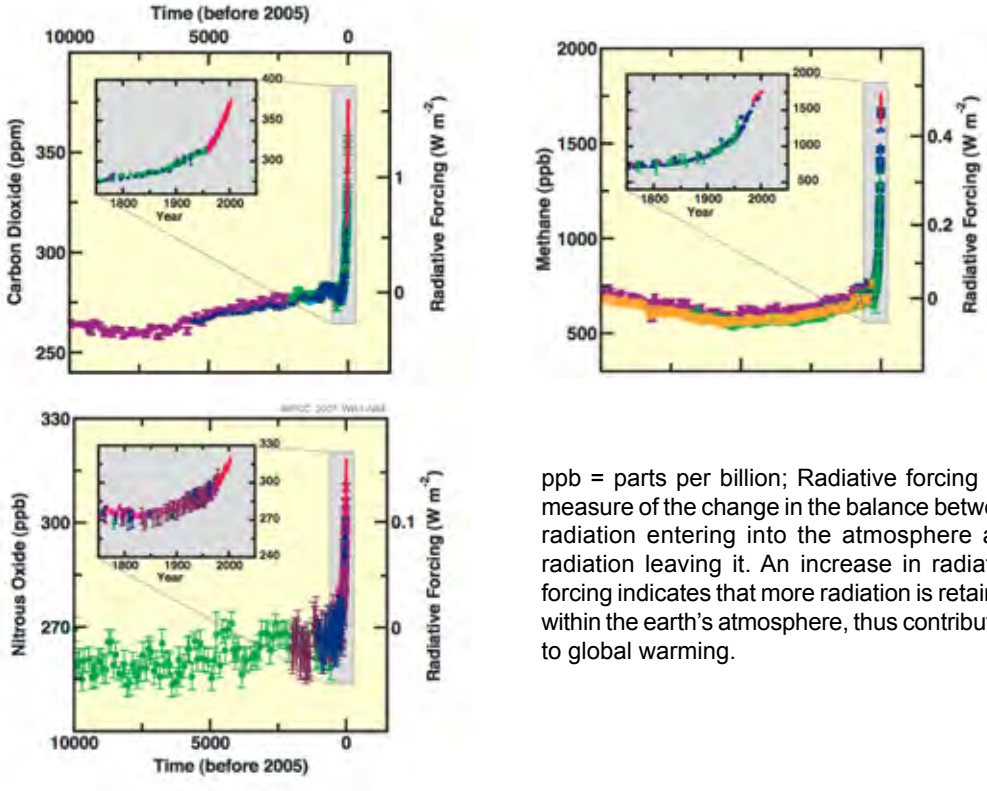


Figure 2: Change in Atmospheric Concentrations of Greenhouse Gases over the Last 10,000 Years[11]



ppb = parts per billion; Radiative forcing = a measure of the change in the balance between radiation entering into the atmosphere and radiation leaving it. An increase in radiative forcing indicates that more radiation is retained within the earth's atmosphere, thus contributing to global warming.

Global Warming Pollutants

Human activities create a variety of pollutants capable of trapping heat within the atmosphere. The most important global warming pollutants include:

- Carbon dioxide – Fossil fuel combustion in cars, power plants and buildings releases carbon dioxide into the atmosphere. Carbon dioxide is the leading global warming pollutant in the United States (and worldwide). Carbon dioxide emissions accounted for approximately 84 percent of the U.S.'s contribution to global warming in 2004.[12]
- Methane – Methane gas escapes from garbage landfills, is released during the extraction of fossil fuels, and is emitted by livestock and some agricultural practices. Methane represents about 9 percent of U.S. global warming emissions.[13]
- Nitrous Oxide – Nitrous oxide is released in automobile exhaust, through the use of nitrogen fertilizers, and from human and animal waste, and is responsible for about 5 percent of the U.S. contribution to global warming.[14]
- Halocarbons – Used in refrigeration, air conditioning and other products, many halocarbons are also global warming pollutants. Halocarbons are responsible for about 2 percent of the U.S. contribution to global warming.[15]
- Black Carbon – Black carbon is a product of the burning of fossil fuels, particularly coal and diesel fuel. Recent research has suggested that, because black carbon absorbs sunlight, it may be a major contributor to global warming, perhaps second in importance only to carbon dioxide. Research is continuing on the degree to which black carbon emissions contribute to global warming, and it is difficult to judge exactly how large a role black carbon might play in the U.S.'s contribution to global warming.[16]

The greenhouse effect is necessary for the survival of life; without it, temperatures on earth would be too cold for humans and other life forms to survive.

However, humans have altered the composition of the atmosphere in ways that intensify the greenhouse effect. Primarily by burning fossil fuels, humans have increased the levels of greenhouse pollutants in the atmosphere—especially in the period since the industrial revolution. Burning fossil fuels creates carbon dioxide, the primary global warming pollutant. (See "Global Warming Pollutants" on page 11 for a description of the types of pollution that contribute to global warming.)

Since 1750, the concentration of carbon dioxide in the atmosphere has increased by more than 35 percent.[9] Carbon dioxide levels are now increasing faster than at any time in more than 10,000 years, and are higher now than at any point in more than 650,000 years.[10] Concentrations of other global warming pollutants have increased as well. (See Figure 2.)

Photo: William Picard

2006 was the second-warmest year ever recorded in New Jersey.

What the Future Holds

Should emissions of global warming pollutants continue to increase, the world will experience dramatic warming over the next century and beyond, with major impacts on the environment, the economy and on human health.

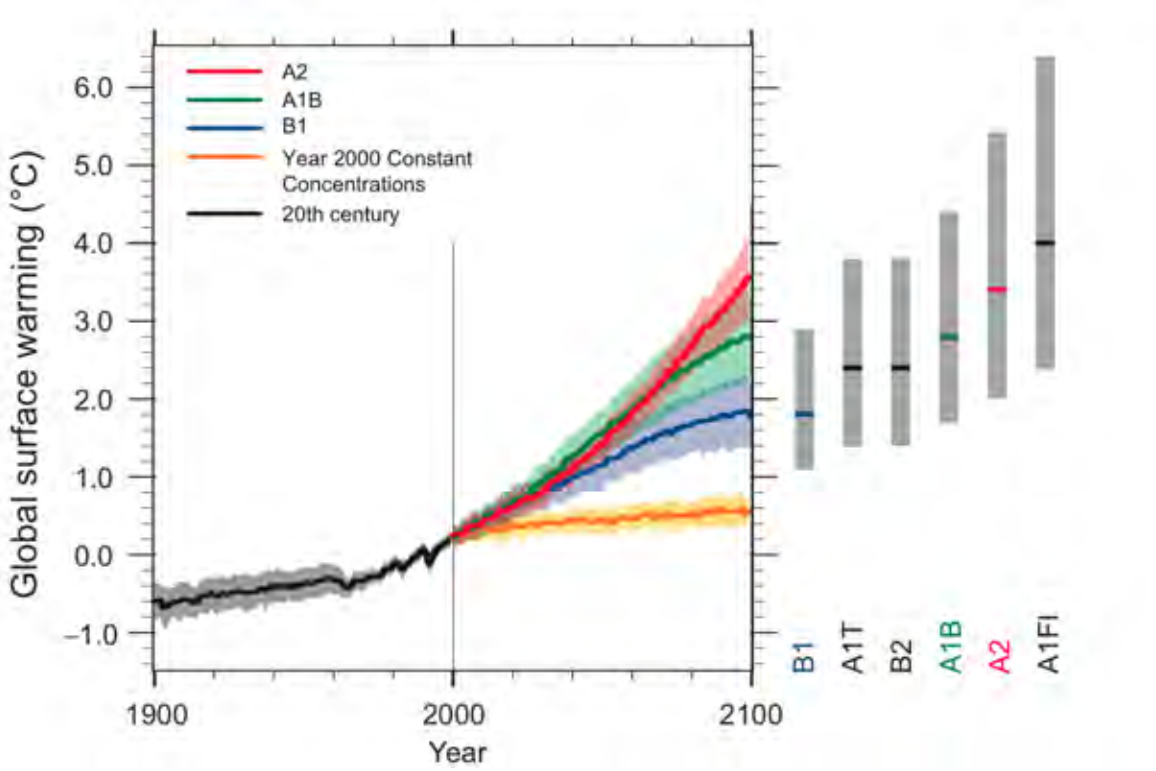
The Intergovernmental Panel on Climate Change (IPCC), the world's leading authority on the science of global warming, recently updated its projections about the future course of global warming. Among their findings:

- Global average temperatures will continue to increase at a rate of 0.4° F per decade over the next two decades. About half of this increase in temperature is essentially "locked in" as a result of the lingering effects of pollution already emitted.
- World average temperatures could increase by another 3 to 7° F above late 20th century levels by the end of this century, depending on future emissions of global warming pollutants.[17] At the highest emission scenario evaluated by the IPCC, estimates of warming range between 4.3 and 11.5° F. (See Figure 3.)
- World average sea level could be expected to rise by another 11 to 17 inches over the next century, with the magnitude dependent on future emissions. At the highest emission scenario evaluated, sea level rise could be between 10 and 23 inches. These estimates of sea level rise do not include the potential for accelerated breakup of the Greenland or Antarctic ice sheets, which would cause a more dramatic rise in sea level.[18] Scientists now consider this issue "more uncertain and possibly more serious than before."[19] For example, recent observations indicate that "the climate system, in particular sea level, may be responding more quickly to climate change" than predicted.[20] Based on the current trend of ice instability in Greenland, ocean levels could increase by as much as 20 to 55 inches (0.5 to 1.4 meters) over the next century.[21]
- Snow and ice cover will continue to contract, heat waves will become more frequent and severe, and hurricanes will likely become stronger.

Notably, the conclusions of the IPCC, because they represent the consensus opinion of thousands of scientists and hundreds of governments, can be considered conservative. For example, some recent research suggests that positive warming feedback loops could have a greater effect – increasing temperatures by as much as 14° F by 2100, under a worst-case scenario.[23]

Changes on this scale will have serious consequences for communities in every corner of New Jersey.

Figure 3: Projected Temperature Increases Under a Variety of Future Emissions Scenarios[22]



Nominal temperature increases in this graphic reflect increases versus a 1980-1999 baseline and do not include increases caused by global warming prior to that period. The IPCC projects future global warming impacts based on a series of scenarios for future global development. The projections in the chart above reflect the following scenarios: "Year 2000 Constant Concentrations" assumes that concentrations of global warming pollutants in the atmosphere remain constant at 2000 levels over time. This scenario assumes that emissions are reduced dramatically and immediately, and is a very unlikely scenario for future emission trends. The remaining scenarios assume different paths for global development and global warming emissions. The scenarios assume roughly these levels of global warming pollutant concentrations in the atmosphere (in carbon dioxide equivalent): B1, 600 parts per million (ppm); A1T, 700 ppm; B2, 800 ppm; A1B, 850 ppm; A2, 1250 ppm; A1F1, 1550 ppm. By contrast, pre-industrial concentrations of carbon dioxide are estimated at approximately 280 ppm and current concentrations are at approximately 379 ppm. The gray error bars to the right of the graph indicate the range of estimates of future temperature increases, with the horizontal line in the center of each bar indicating the "best estimate" of future increase in global average temperature.

Global Warming Will Affect Every Corner of New Jersey

Global warming poses a severe threat to the future of New Jersey's environment, economy, and the health and welfare of its citizens.

If global warming pollution across the world continues to rise, New Jersey will be a different place in 100 years. The local impacts of global warming in the state could include impacts as varied as the inundation of the Wildwood Boardwalk by rising seas; saltwater infiltration into Camden's water supply, more frequent flash flooding in the Delaware River valley, increased heat-wave deaths in Newark, and the invasion of the Southern Pine Beetle into the New Jersey Pinelands.

In this report we explore the possible consequences of global warming for local communities across the state. In doing so, three cautions are in order. First, the impacts of global warming are likely to be complex and interrelated. For example, agriculture in New Jersey could benefit from longer growing seasons, increased carbon dioxide in the atmosphere, and higher overall precipitation. It could also be harmed by stronger storms, more frequent droughts, and increased risk of pest infestation. Determining how the various anticipated impacts of global will balance out is difficult, and it becomes even more difficult knowing that global warming will likely deliver some impacts that take us by surprise. We don't have perfect knowledge of how global warming will affect our lives and our environment in the years to come. But we do know enough to be concerned.

Second, current scientific models are much better able to predict impacts of global warming at the global or continental scale than for small geographic regions like New Jersey. Many of the impacts described in this report—including rising sea level, greater risk of heat-related deaths and smog, and shifts in the composition of species – are projected to impact the entire state of New Jersey and the mid-Atlantic region as a whole. By focusing in on the impact of particular problems in particular parts of the state (e.g., heat-related deaths in Newark), we do not intend to suggest that the same impacts will not also affect other parts of the state. We do so merely to illustrate the breadth of the impacts global warming will have on life in the Garden State.

Finally, any impacts of global warming depend critically on future trends in global warming pollution in New Jersey and worldwide. If we move quickly to reduce emissions of global warming pollutants, there is still time to avoid many of the global warming impacts described in this report.

The Shore: Inundated Boardwalks, Receding Beaches

The Jersey Shore is one of America's great vacation destinations and a welcome summertime respite for visitors from across the eastern seaboard. The Shore supports a $16 billion dollar tourism industry and provides jobs for hundreds of thousands of New Jersey citizens.[24]

The Shore is also delicate. While people have built boardwalks, summer homes and other structures along the Shore in the expectation that the shoreline will always be roughly where it is today, nature is constantly reshaping the shoreline in ways large and small. Global warming – which is expected to bring higher seas and more intense storms – could bring even greater changes to the Shore, in some cases wiping out beloved places, eroding beaches and inundating coastal marshes.

The Wildwood Boardwalk is a famous Shore amusement park and tourist attraction in Wildwood.[25] However, because of global warming, rising sea level could inundate the area around the roller-coasters and Ferris wheels by the end of this century. The boardwalk is located in a very low-elevation part of the Jersey Shore, at risk of being swallowed by the ocean. (See Figure 4.)

Figure 4: The Wildwood Boardwalk is Vulnerable to Sea Level Rise

Global warming has already contributed to a measurable rise in sea level along New Jersey's coastline. During the 20th century, relative average sea level along the Jersey Shore rose by 35 centimeters, or about 14 inches.[26] (Approximately half of that rise was due to human-induced climate change, and the other half due to land subsidence.)[27]

Given the sea level rise forecast by the Intergovernmental Panel on Climate Change (IPCC) and local rates of land subsidence, relative sea level along the Jersey Shore could rise by 16 to 31 inches by the end of the century (or between 0.4 and 0.8 meters).[28]

Sea level rise within the range of these forecasts could inundate much of Wildwood, making North Wildwood into an island, separated from Wildwood Crest by shallow flooding across New Jersey Avenue. Much of the Shore would be affected. A sea level rise of 24 inches, for example, would put approximately 1 percent of the state's land area underwater.[29]

Erosion of the Beach at Cape May Point

Scientists estimate that about 80 to 90 percent of the beaches along the eastern coast of the United States are eroding in areas not modified by engineering projects or localized sand build-up.[30] This trend is mirrored on beaches worldwide. Rising sea levels enable waves to reach further up the shore, where they can disturb otherwise stable ground and cause erosion.[31]

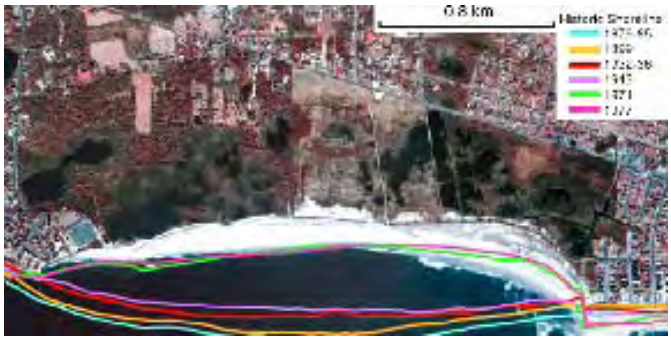
Located on the southern tip of New Jersey, Cape May Point—known for its picturesque lighthouse, serene beaches, and migratory birds—is particularly at risk. Over the past century, the shoreline at Cape May Point has receded inland as sea levels have gradually risen. (See Figure 5.)

Global-warming induced sea level rise will accelerate the erosion of Cape May Beach and other Shore beaches in the future.

Keqi Zhang at Florida International University and his colleagues estimate that New Jersey is losing shoreland at a rate of 36 meters for every 0.3 meters that ocean levels rise. This rate of erosion is faster than along the shores of most other East Coast states.[33]

At this rate, the average Shore beach could retreat inland between 50 and 150 meters by the end of this century, without human intervention.[34] With intervention, such as the installation of sea walls, it is more likely that beaches would shrink out of existence, trapped between rising seas and immovable structures.

Figure 5: Historic Shoreline Positions at Cape May Point[32]



New York City Metropolitan Area: Vital Transit Infrastructure Under Threat

The transportation links that make the movements of goods and people possible are critical to the continued prosperity of New Jersey, and the entire tri-state region.

Every day, New Jerseyans from across the state commute in and out of New York City to go to work. Hundreds of thousands of people ride trains into the city every day, and hundreds of thousands more cross into the city on roads and bridges. The region

is also home to some of the busiest airports in the world. More than 30 million passengers travel through Newark Airport every year.[35] Moreover, every year more than 18 million tons of goods are shipped through infrastructure at Port Newark and Port Elizabeth, and onward by truck to every part of the country.[36]

However, much of this infrastructure is vulnerable to tidal surge flooding during major storms. A number of critical transportation links – including the Holland Tunnel, LaGuardia Airport and the shipping terminals at Port Newark and Port Elizabeth along Newark Bay – are located relatively close to sea level. (See Figure 6.)

A storm surge of 6 to 12 feet would cause increasingly severe interruptions in transportation service within the region.[37] In the event of a storm of this severity, New Jersey residents could see both tunnels to New York flooded, flooding of the New Jersey Turnpike as it crosses the Meadowlands, and disruption of air travel and shipping.[38]

New Jersey has experienced some near-miss hurricanes, powerful tropical storms and several large northeasters with large tidal surges and heavy rains, highlighting the state's vulnerability. For example:

- In September 1944, the Great Atlantic Hurricane paralleled the coast of New Jersey as a Category 2 storm, causing a tidal surge of more than 9 feet. The storm damaged more than $250 million worth of property (in 2005 dollars).[39]
- On Halloween in 1991, a huge northeaster caused significant bay flooding, extreme beach erosion and more than $100 million in property damage (2005 dollars).[40]
- In September 2003, Hurricane Isabel passed to side of New Jersey, but buffeted the state with tropical storm-force winds. The storm caused a tidal surge of up to 10 feet and more than $50 million in property damage (2005 dollars).[41]

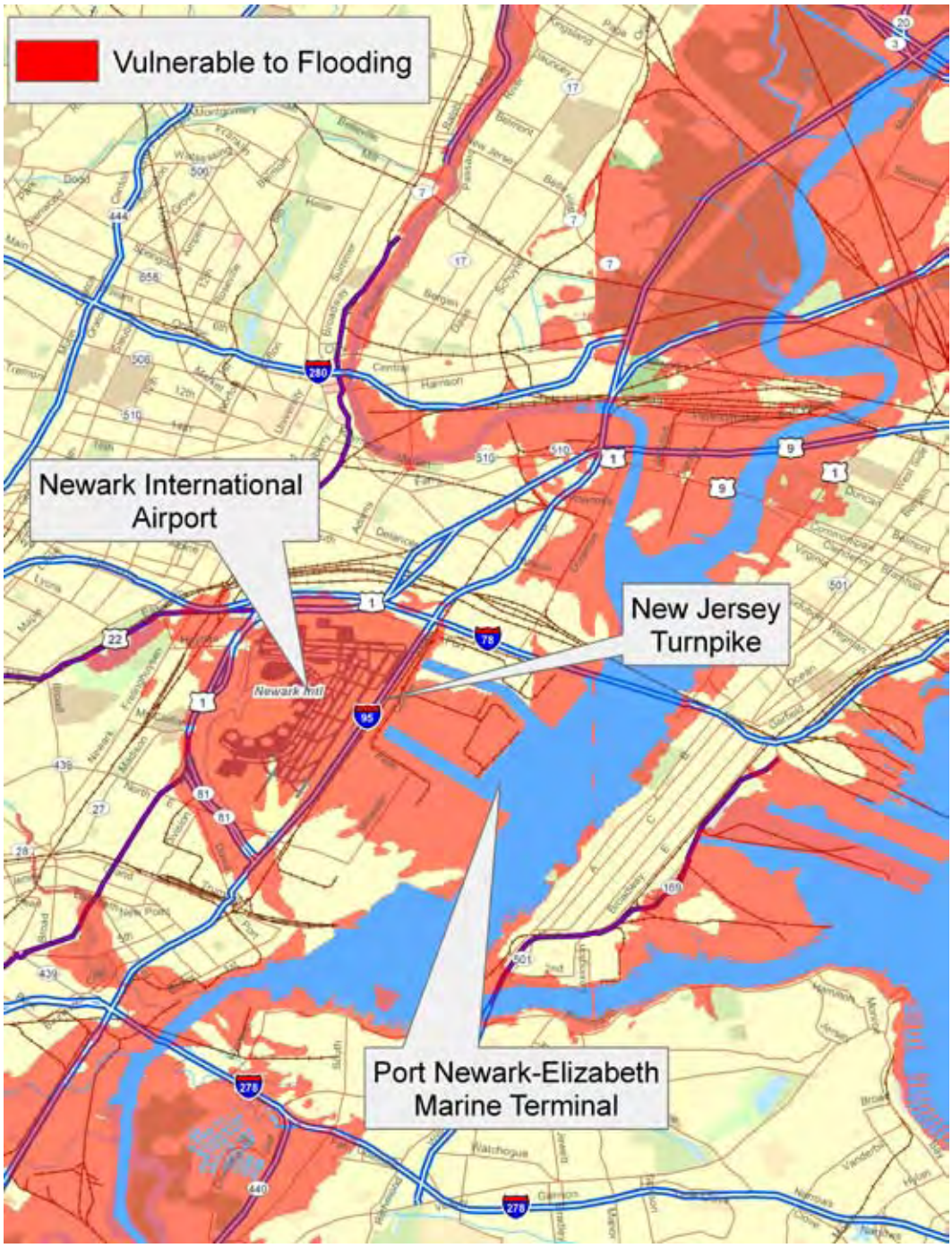
But perhaps the best example of the vulnerability of the regional transportation system to a major storm occurred in December 1992, when a severe northeaster bore down on New Jersey and New York City, causing a tidal surge of up to 12 feet.[42] The storm:

- Flooded a runway at LaGuardia Airport, shutting down all flights;

Photo: William Picard

Critical transportation infrastructure, including Newark International Airport and the Port Newark-Elizabeth Marine Terminal (pictured here) will be vulnerable to more frequent flooding because of global warming.

Figure 6: 100-year Storm Surge Flood Area after 16 to 31 Inches of Sea Level Rise



- Closed the Staten Island Ferry;
- Shut down PATH train service from New Jersey to New York and several New Jersey Transit lines;
- Flooded the Hoboken Train terminal, with the tracks underwater; and
- Short-circuited electric generators for the New York subway system, shutting down service for several hours and causing major delays.

Global warming threatens to increase the vulnerability of the transportation system to flooding in two key ways. First, an increase in sea level will increase the frequency of severe tidal surge flooding. A storm that causes minimal flooding now would be much more serious after a sea level rise of up 31 inches. Second, global warming could increase the severity of storms that strike the region, making it more likely that a given storm could lead to a severe tidal surge.

Increased Frequency of Tidal Surge Flooding

Tidal surge flooding along the coast of New Jersey and New York will happen more often as time goes on because of sea level rise caused by global warming.

Based on historic flood patterns, the Federal Emergency Management Agency estimates that once in every 100 years, a storm will cause a tidal surge of 9.5 feet.

However, a storm surge of this severity could happen three to four times more often after a sea level rise of 24 inches. Add another 24 inches of sea level rise, and dangerous flooding could happen every 5 years.[43] And under the worst-case scenario in the 2007 assessment of the Intergovernmental Panel on Climate Change, 100-year tidal surges could occur as frequently as every three to four years.[44]

By the end of the century, flooding could inundate the Holland Tunnel, La Guardia Airport, and the New York City Passenger Ship Terminal with up to 3 feet of water every 5 years on average.[45] Newark Airport, the Lincoln Tunnel, and up to 20 PATH and New York City subway stations would be vulnerable to any storm of 50-year intensity or greater (meaning statistically likely to happen twice per century, on average).[46]

Storm damage to transportation and port infrastructure could have serious economic consequences. Scientists at Columbia University estimate that altogether, increased tidal surge flooding due to sea level rise could triple the amount of flood damage faced by the region by the year 2100. Increased tidal surge flooding could cause an estimated annualized average of $1.5 billion in damage per year.[47]

These estimates do not take into account the possibility that global warming could increase the strength of storms in the mid-latitudes, potentially increasing the frequency that major storms can be expected to strike, and further increasing how often flooding occurs.

Photo: Richard Bussink

By 2100, the Holland Tunnel could be flooded by 3 feet of water every 5 years on average, because of sea level rise induced by unchecked global warming.

Stronger Hurricanes and Mid-Latitude Storms

While hurricanes are a relatively rare occurrence in New Jersey compared to places further south, global warming will likely make the hurricanes that do occur stronger.

The Atlantic hurricane season of 2005 provides a glimpse at what the future may hold. This season was the worst ever recorded, with the most named storms (28), the most hurricanes (15), the most Category 5 hurricanes (4), the most major hurricanes to hit the U.S. (4), the costliest hurricane (Katrina, which caused more than $80 billion in damage), and three of the six strongest hurricanes recorded (Wilma, the strongest ever, plus Katrina and Rita).[49]

Scientists have unearthed evidence that Atlantic hurricanes have become more powerful and more destructive over the last three decades, and global warming is at least partly responsible. For example:

- The number of severe hurricanes (category 4 and 5) has doubled since 1970.[50] Hurricane wind speed and duration have increased by 50 percent since the 1970s.[51]
- Warmer oceans (caused by global warming) can lead to stronger and more intense hurricanes.[52] For example, scientists at the University of Colorado used satellite images to show that Hurricane Katrina gained strength from unusually warm waters in the Gulf of Mexico, evolving from a Category 3 to a Category 5 hurricane in just nine hours.[53]
- Scientists at the National Center for Atmospheric Research attributed half of the extra warmth in the tropical Atlantic Ocean during the extreme 2005 hurricane season directly to global warming.[54]

As global warming continues to increase ocean temperatures, stronger hurricanes will likely result.

NOAA

The hurricane season of 2005, which produced Hurricane Katrina (pictured here), was the most active hurricane season on record. While it is impossible to blame any single weather event on global warming, many scientists believe that warmer oceans—a direct result of global warming—lead to stronger storms.

- According to NASA, continued warming will likely increase the intensity of hurricanes, causing a typical hurricane to strengthen by about a half category (on the Category 1 through 5 scale of hurricane strength).[55] In other words, the maximum wind speed in a typical hurricane would increase by about 6 percent and rainfall rates would increase by about 18 percent within 60 miles of the storm center.
- The Intergovernmental Panel on Climate change notes that while there is still some uncertainty about how global warming will affect the frequency and strength of tropical storms, the picture is clearer in the mid-latitudes. Outside of the tropics, global warming will increase the strength of mid-latitude storms, increasing wave and tidal surge heights, although storm frequency could decrease.[56]

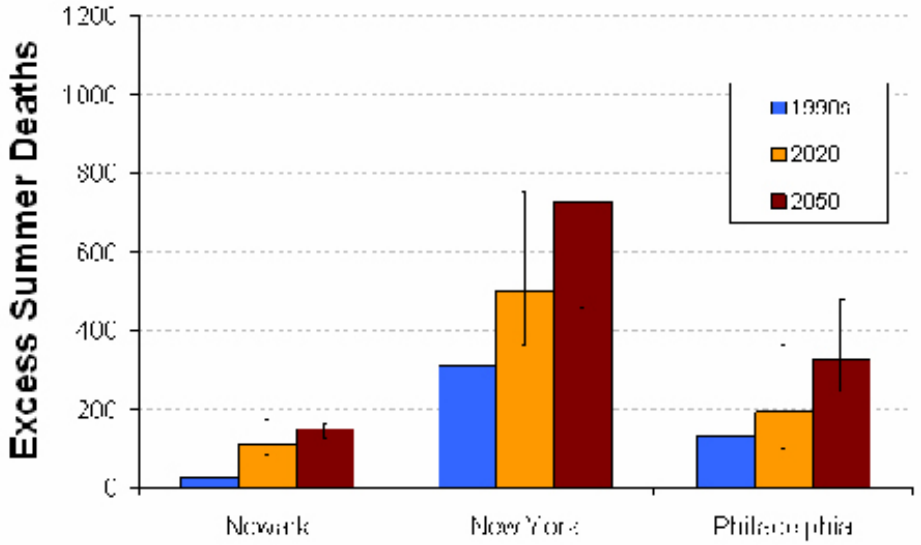
If global warming increases the strength of hurricanes and mid-latitude storms, it will increase the vulnerability of New Jersey's critical transportation infrastructure to the impacts of a major tidal surge. If a Category 4 hurricane struck Newark Bay and New York City at the sea levels expected near the end of the century, it could cause in the range of $250 billion in damages—a severe blow to the economy which would be felt nationwide.[57]

Urban New Jersey: More Heat-Related Deaths

Summer in the city isn't like summer in the country. Anyone who has walked barefoot across the street on a hot summer day knows firsthand that pavement absorbs a lot more heat than grass.

While rural areas tend to cool off at night, the asphalt and brick in cities continue to radiate heat through the night, keeping temperatures elevated in cities around the clock. Add the waste heat from air conditioners, driving and other city activities, and cities become islands of heat. For example, Newark tends to be more than 5° F hotter than rural parts of New Jersey.[58]

Figure 7: Estimated Additional Summer Heat-Related Deaths in Major Cities in and Around New Jersey Due to Global Warming[68]



As a result, Newark and other urban areas in New Jersey will be more vulnerable to the public-health impacts of increased heat waves caused by global warming.

During heat waves, prolonged periods of elevated temperatures in cities can have a serious impact on public health. During a heat wave, individuals unable to maintain a stable temperature of 98° F suffer from heat exhaustion, heat stroke and eventually, death. The elderly, the young or the chronically ill are the most vulnerable. In the United States, heat waves are currently responsible for more deaths than hurricanes or any other severe weather event.[59]

One of the worst heat waves in recent history occurred in Europe in August 2003, centered on France. Temperatures soared to above 100° F and remained abnormally elevated for two weeks. At least 35,000 people died as a result, including 14,802 in France alone.[60]

In Newark in the 1990s, hot temperatures (defined as days with high temperatures above 90° F) affected the region for an average of 14 out of 92 summer days.[61] However, unchecked global warming will make such hot days much more frequent:

- By the 2020s, the number of hot days could more than double.[62]
- By mid-century, the number of hot days could more than quadruple, affecting 60 out of 92 summer days, on average.[63]
- By the 2080s, the number of hot days could rise to between 40 and 120 per year.[64]
- The number of days per year with temperatures over 100° F in New York could rise from two today to 25 toward the end of the century.[65]

As a result of the increased strength and duration of heat waves, the number of heat-related deaths in Newark is expected to more than triple by 2020 (compared to a 1990s baseline).[66] By the year 2050, the number of summer heat-related deaths in Newark could be more than 5 times higher. (See Figure 7). While global warming will also reduce deaths from cold in the winter, the increase in heat-related deaths will more than offset this potential benefit. (Scientists estimate that the number of excess summer deaths in 2050 will exceed the number of prevented deaths in the winter by more than four-fold.)[67]

Suburban New Jersey: Worsened Smog Pollution

Extended heat waves will enhance the conditions that lead to the formation of ground level-ozone, or smog—already a serious threat to public health across New Jersey. Scientists forecast that this effect will be most pronounced in New Jersey's more suburban counties, including Ocean, Hunterdon, Somerset and Mercer counties.

New Jersey already has a serious problem with air quality. Every one of the state's 14 counties are in non-attainment status under the federal Clean Air Act because of high levels of summer smog pollution.[69] In the past five years (2002-2006), smog levels in New Jersey have exceeded federal health standards on as few as 14 and as many as 44 days per year.[70]

High smog levels happen most frequently when the weather is hot and sunny. For example, the worst ozone episode of 2006 happened on July 17 and 18, when high temperatures across much of New Jersey rose as high as 101° F.[71]

More frequent heat waves caused by global warming will increase the frequency of prime conditions for creating smog pollution. This could have serious consequences for public health in New Jersey.

Dr. Kim Knowlton at the Mailman School of Public Health at Columbia University in New York worked with her colleagues to estimate how ozone levels will change in northern New Jersey under global warming.[72] Her forecast takes into account possible changes in the emissions of smog precursors, population change, and increased temperatures caused by global warming.

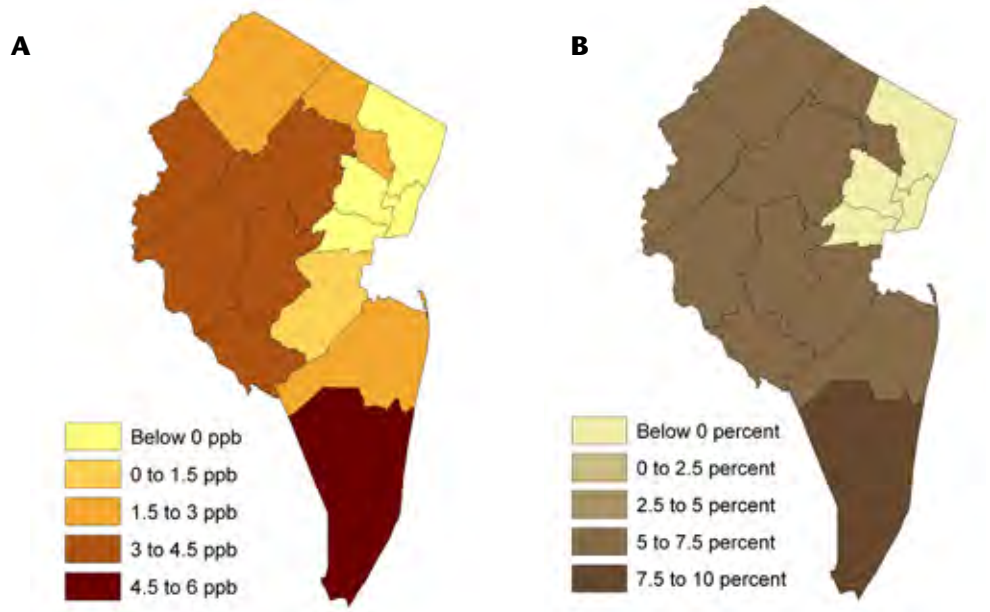
Dr. Knowlton found that global warming could substantially increase smog levels across New Jersey by the 2050s, especially in more suburban counties.[73] (See Figure 8.) The model predicted small decreases in smog levels in the urban core, perhaps because of increased NOx emissions soaking up excess ozone.[74]

Increased levels of smog would harm public health in New Jersey. Smog exposure damages lung health, triggering asthma attacks and long-term structural damage to the lungs. It is especially dangerous for

Table 1: Increase in Smog Levels and Smog-Related Deaths in Suburban Northern New Jersey in 2050 (vs. the 1990s).[75]

County	Increase in the Mean Daily 1-Hour Maximum Ozone Level (ppb)	Percent Increase in Smog-Related Deaths
Ocean	6.0	9.7%
Hunterdon	4.3	6.8%
Somerset	4.2	6.6%
Mercer	4.0	6.5%
Warren	3.6	5.9%
Morris	3.1	5.0%
Sussex	2.8	4.6%
Passaic	2.3	3.9%
Monmouth	1.7	3.2%
Middlesex	1.4	2.6%
Union	0.0	0.0%
Essex	-0.1	-0.2%
Bergen	-0.7	-0.5%
Hudson	-2.8	-6.3%

Figure 8: Estimated Changes in Smog Levels (A) and Smog-Related Deaths (B) in New Jersey in 2050 (vs. 1990s)



The average summer daily maximum 1-hour smog concentration, and the corresponding percentage increase in the number of summer deaths due to smog, is projected to increase more in suburban counties of New Jersey than urban counties under global warming.

The Health Impacts of Smog

Smog, or ground-level ozone, is a public health hazard. When inhaled, it damages lung tissue and causes short-term swelling. With long-term exposure at even low levels, it causes permanent and irrevocable damage.

Scientists have known for well over a decade that ozone at levels routinely encountered in New Jersey causes reddening and swelling of lung tissue and reduces the elasticity of lung tissues over time.[76] Ozone makes lung tissues more sensitive to allergens and less able to ward off infections.[77] It scars airway tissues. Children exposed to ozone develop lungs with less flexibility and capacity than normal. During high smog days, otherwise healthy people who exercise can't breathe normally.[78]

The effects of ozone exposure are life-long, including permanent decreases in lung function and increased incidence of asthma. For example:

- College freshmen who were raised in less polluted areas have lungs that work better than their schoolmates who grew up in polluted cities. For example, freshmen at the University of California-Berkeley or at Yale who have lived in areas with high ozone levels can't breathe as well as freshmen from cleaner areas.[79]
- The Southern California Children's Study indicates that exposure to ozone can cause asthma in children.[80] Children who exercise frequently in smoggy areas are more than three times as likely to develop asthma as those in cleaner parts of the country.

Global warming, by creating hotter summers, could increase the amount of smog in New Jersey, thus increasing the level of harm to our health.

the young and elderly. (See "The Health Impacts of Smog," above.)

Dr. Knowlton measured the impact of increased smog levels in terms of smog-related deaths, an indicator of much more widespread damage to public health. She found that global warming could increase the number of smog-related deaths, especially in more suburban areas of New Jersey. Table 1 lists the forecast increases in smog levels and associated increases in smog-related deaths for northern New Jersey counties.

Highlands Corn and Pinelands Blueberries: Longer Growing Seasons, More Threats to Crop Health

From the corn fields in the Highlands to the blueberry farms and cranberry bogs in South Jersey's coastal plain, New Jersey has a rich agricultural history that lives on today. New Jersey farms produce more than $300 million dollars worth of crops, fruits and vegetables every year.[81]

Global warming will change New Jersey agriculture, and the impacts are likely to be mixed in the coming decades. Global warming is often seen as a "good news" story for agriculture – at least in northern states. The recent report of the Intergovernmental Panel on Climate Change (IPCC) found that climate change in the early years of this century could increase the productivity of rain-fed agriculture by 5 to 20 percent on average.[82] Growing seasons are already getting longer in the region and will likely be extended further in a warming world.[83]

However, global warming won't help all types of farmers, and in certain locations it may have negative impacts. Global warming will also pose new threats that could give New Jersey farmers plenty to worry about in the next few decades.

Highlands Corn

New Jersey's agricultural heritage still lives on in the New Jersey Highlands, a stretch of the Appalachian Mountains crossing the state's northwestern corner. The Highlands retain much of their wild character, and it is still possible to imagine the first European settlers building homesteads and plowing fields along the many streams and lakes in the area.

Corn is one of the many crops farmers grow in the Highlands. In fact, Warren County (on the western edge of the Highlands) is the second-largest source of corn for grain in New Jersey. Warren County farmers plant more than 21,000 acres of corn fields, harvesting more than 2 million bushels of corn per year.[84]

Corn farmers in the Highlands might find that longer growing seasons and higher carbon dioxide concentrations in the air make their corn grow faster. However, global warming will also create or exacerbate risks to their crops that could pose serious challenges to their livelihood in the future. Among those risks are agricultural pests, weeds, and excess heat.

Warmer temperatures could increase the winter survival numbers of agricultural pests.[85] Pests are already responsible for destroying about a third of crop production in North America. Farmers may find pressure to increase pesticide applications in the future to control larger pest populations.[86]

Just as the longer growing season will promote higher crop yields, longer growing seasons will promote the growth of weeds and other unwanted plants. Farmers may find that their weed problems grow along with increasing temperatures.

Corn plants are also sensitive to high temperatures and excessive moisture, both likely to occur more frequently under global warming.[87]

Pinelands Blueberries

Blueberries, which thrive in the unique soil of the New Jersey Pinelands, are one of the state's most iconic crops. The highbush blueberry was first domesticated by Elizabeth Coleman White, the daughter of a prominent New Jersey cranberry grower.[88] Today, blueberry farmers cultivate more than 7,500 acres and produce more than $40 million worth of New Jersey blueberries every year.[89] New Jersey ranks second only to Michigan in blueberry production.[90]

While global warming could lengthen the growing season of the blueberry and

Photo: NJ Department of Agriculture

Blueberries are one of New Jersey's iconic crops.

possibly increase fruit yield, it will also bring challenges in the form of shifting the range of the plant, increased chance of drought, and potentially more harsh weather extremes.

Right now, the southern range for highbush blueberries is in Maryland. However warmer temperatures in the past few years have reduced the health of Maryland's crop.[91] As temperatures continue to rise, the southern range of the blueberry will move north. Worldwide in the last half of the 20th century, 1,700 plant, animal and insect species shifted toward the earth's poles at an average rate of about 4 miles per decade.[92] Eventually, if temperatures keep rising, the blueberry will not grow well in the Pinelands, where it was first cultivated.

Higher summer temperatures are projected to increase evaporation of water from farm soils, thus leading to increased potential for drought. Global warming will tend to increase surface water temperatures, increasing evaporation from streams and lakes and leading to lower river flow and lower lake levels. The mean annual flow of the Delaware River at Trenton, for example, could decrease about 15 percent if average temperatures warm 4.5°F and precipitation remains unchanged.[93]

Finally, global warming could bring more extremes of heat and precipitation, which could damage blueberry crops. For example, New Jersey was declared a federal disaster area because of crop damage from drought, excessive precipitation, excessive heat and high humidity during the summer of 2005; and a second disaster was declared during the summer of 2006 because of excessive precipitation, high wind, hail and high humidity.[94]

While global warming may have some positive impacts on agriculture in New Jersey, it also increases a variety of risks to New Jersey farmers.

Worldwide, if global average temperatures rise more than 2.7 to 4.5° F, IPCC scientists expect "predominantly negative consequences" for natural resources like water and food.[95]

The Delaware River Valley: More Dangerous Floods

In 2004, 2005 and 2006, the Delaware River Valley experienced four extremely severe flood events in succession—causing the worst flooding in half a century.[96]

On July 2004, an extremely severe 1,000-year thunderstorm hit the Rancocas River Basin in Burlington County, a tributary of the Delaware. The storm dropped more than 13 inches of rain on Tabernacle within 12 hours, causing record flash flooding. The storm damaged or destroyed 51 dams and 14 bridges in Burlington County, closed major roads including the New Jersey Turnpike, and caused millions of dollars of damage to cranberry bogs and other farm fields.[97]

In September 2004, the remnants of Hurricane Ivan collided with a slow-moving cold-front over the upper Delaware River valley, causing large amounts of rainfall. The resulting flood caused severe property damage. For example, it washed a home in Harmony Township (Warren County) from its foundation and swept it down the river until it broke apart on the Easton-Phillipsburg Free Bridge.[98]

In April 2005, another unusually large storm struck the Delaware River Valley. The flood damaged more than 3,000 homes and a dozen bridges upstream from Trenton, many of which had already suffered damage in the previous flooding.[99]

A fourth flood struck in June 2006. During this event, the Delaware River near Easton, Pennsylvania reached a flow level of 1.5 million gallons per second, enough to cover a football field in 4 feet of water every second.[100]

The floods caused $2 million in damage

Photo: Dr. David A. Robinson, NJ State Climatologist

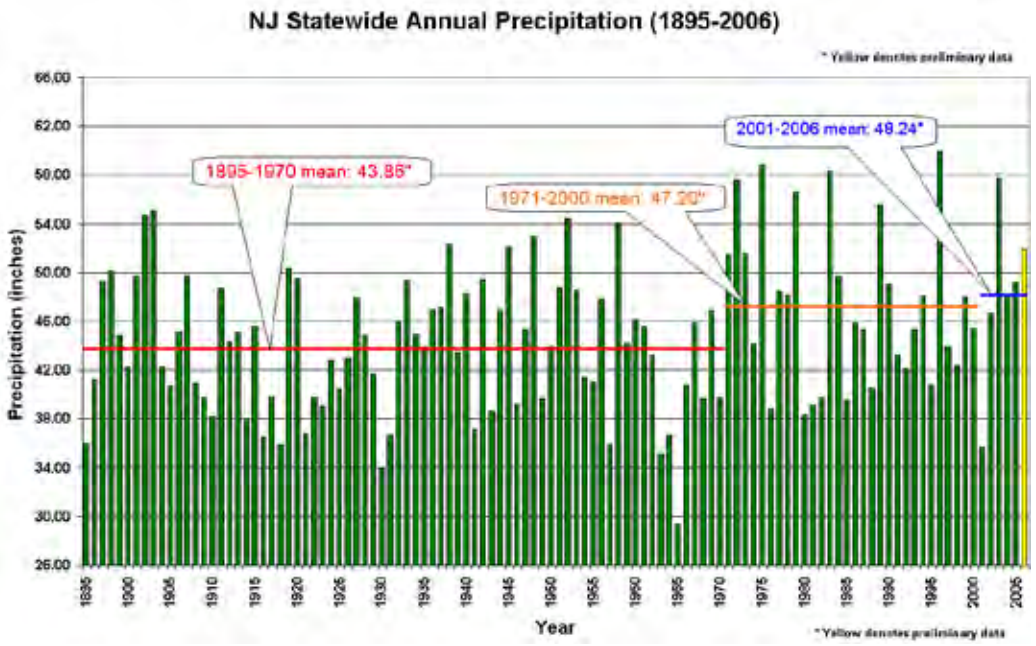
On April 16, 2007, Manville flooded during one of the wettest April months in New Jersey history.

at the New Jersey State House parking garage in Trenton and destroyed Bull's Island Recreation Area in Hunterdon County.[101] Altogether, the four floods caused more than $150 million in estimated property damage.[102]

And the Delaware River Valley is not the only part of New Jersey that faces risks from flooding after extreme precipitation events. For example:

- In September 1999, Hurricane Floyd crossed New Jersey as a tropical storm, dropping up to 13 inches of rain, flooding five rivers (including the Raritan), knocking out power to more than 650,000 citizens, and killing six people.[103] Stronger hurricanes, a possible impact of global warming, could yield increased rainfall volumes and increased risk of flash flooding. On average, NASA predicts that warmer ocean temperatures within the century could increase rainfall by 18 percent within 60 miles of the center of a given storm.[104] (See "Stronger Hurricanes" on page 20.)
- A huge northeaster hit New Jersey in April 2007, bringing five to nine inches of rain, causing hundreds of millions of dollars in flood damage, and killing at least three people.[105] The flooding hit Passaic, Bergen and Somerset counties the hardest. Flooding submerged parts of Manville and Bound Brook. Manville was reachable only by boat for three days.[106] More than 3,000 people were evacuated from their homes, and the flooding caused severe delays at local train lines and airports.[107] Hoboken became an island, with roads in all directions submerged under up to 3 feet of water.[108]

Figure 9: New Jersey Annual Precipitation[111]



While it is impossible to attribute any of these individual events to global warming, they do fit a pattern of increased weather extremes that scientists believe could be one of the impacts of global warming.[109] Trends in New Jersey's weather over the past several decades may already be providing evidence. For example:

New Jersey has been getting wetter. An analysis by the Office of the New Jersey State Climatologist shows that the mean annual precipitation over the 1971-to-2005 period was more than three inches higher than the average from 1895 to 1970, and the mean annual precipitation from 2001 through 2006 was another inch higher still.[110] (See Figure 9.)

But while total precipitation has increased in recent years, New Jersey has also experienced a series of damaging droughts. The state experienced serious drought conditions at times during 1998, 1999, 2001, 2005 and 2006.[112] August and September 2005 were the driest combined August-September on record. They were followed immediately by the wettest single month ever recorded in New Jersey (October 2005). March 2006 was the driest March on record, and June 2006 was the fifth-wettest June.[113] 2001 was one of the driest years on record in New Jersey, while the fall of 2006 was the wettest ever recorded in New Jersey.[114]

In a future with more extreme weather events like New Jersey has experienced in the last decade, flooding could become a more common experience for New Jerseyans across the state.

Camden: Water Supply at Risk

In 1965, Camden's water supply started to become salty and less suitable for drinking. It appeared that salt from the ocean was somehow entering the underground aquifer that cities in the region relied upon to supply fresh water to its citizens.[115]

It turned out that a severe drought in late 1964 had reduced the flow of fresh water in the Delaware River, allowing brackish ocean water to migrate further up the river and contaminate normally fresh groundwater supplies.[116]

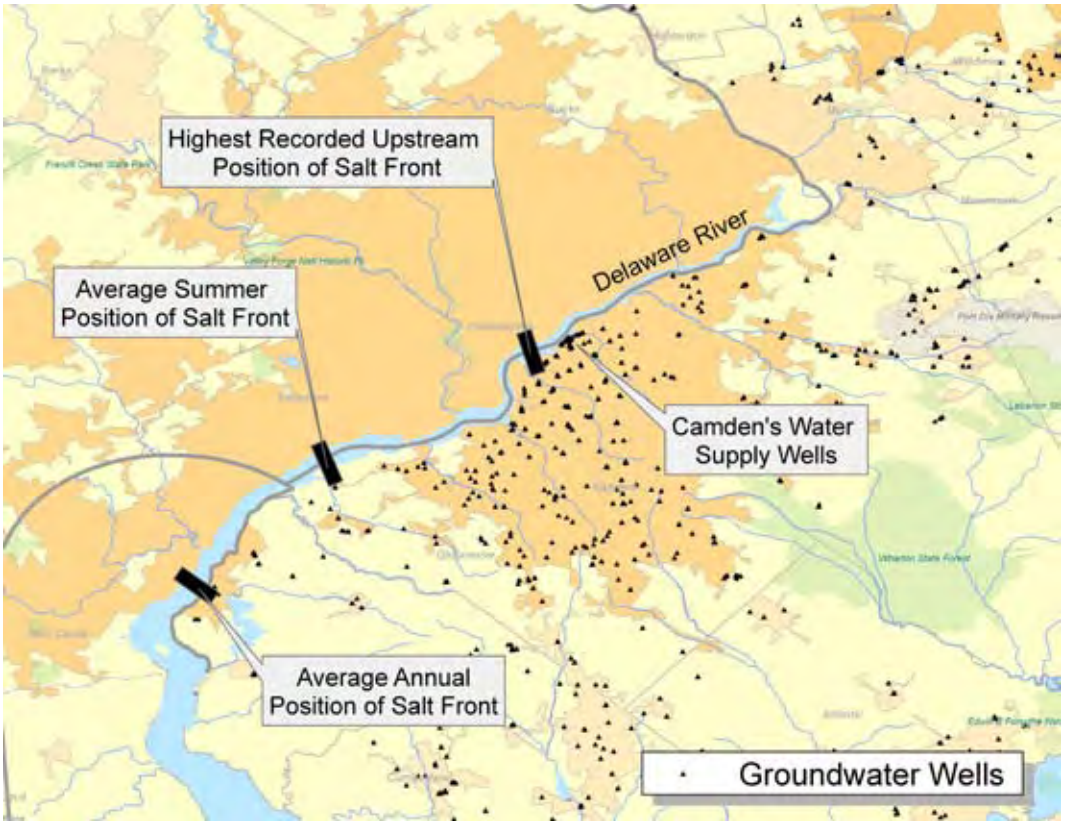
Before Camden was settled, water from the underground aquifers flowed outward into the Delaware River. However, now that people are pumping water from the aquifer, water flows the opposite direction, from the river in to recharge the aquifer.[117]

Normally, the Delaware River flow feeds fresh water coming from upstream rainfall into Camden's aquifer. However, during periods of extreme drought and low river flow, the mixing zone between the Delaware River and the ocean can move upstream, bringing brackish, salty water.[118]

The location in the river where the salt concentration is 250 milligrams per liter is called the "salt front." The salt front is usually found near Wilmington, Delaware during periods of average streamflow. During the summer, with typically lower levels of rainfall, the salt front moves up-river, toward Chester, Pennsylvania.[119]

During the 1964 drought, the salt front moved up toward Philadelphia and Camden, reaching its highest recorded position.[120] (See Figure 10.) As a result, salt water was able to flow from the unusually brackish

Figure 10: Range of the Salt Front Between the Delaware River and the Atlantic Ocean



Normally, the mixing zone between salt and fresh water in the Delaware River is below Wilmington, DE. However, when fresh water flow declines in the summer, the salt front moves upriver toward Bridgeport. During an extremely low period of water flow in 1964, salty water reached even further upriver, contaminating Camden's water supply wells. Sea level rise caused by global warming will make this happen more frequently in the future.

river and into the aquifers supplying drinking water to the city of Camden. The city's water supply contained abnormally high levels of salt for months afterward.[121]

Camden could find increasing levels of salt water in its drinking water wells as a result of global warming. In the Delaware River, sea level rise caused by global warming will likely have much the same effect as the drought of 1964. Sea-level rise will push the salt front higher up the Delaware River.

If the salt front reaches the Camden area, the city may have to shut its water supply wells and find an alternate source of water. For example, saltwater intrusion has forced water officials in Cape May County to abandon at least 10 public supply wells and more than 100 domestic supply wells over the last four decades.[122] The city of Cape May opened a desalination plant in the 1980s as an alternate source of water —with a price tag for the average household of $85 per year.[123]

If the salt front reaches higher, it could also affect the water supply for Philadelphia. For example, a rise in sea level greater than 29 inches would likely push the brackish water line above Philadelphia's water supply intake along the Delaware River at Torresdale.[124]

If the flow in the Delaware increases due to consistently higher levels of rainfall, it could mitigate the impact of sea level rise on the water supply in the region. However, there is reason to expect that more weather extremes and faster evaporation will make the river flow more variable, with periods of both flooding and drought.

As a result, communities near the expanding salt front may find that global warming means less fresh water.

Photo: Harris Shiffman

Photo: David Kay

Top: Red Knot; Bottom: Horseshoe Crab The Red Knot relies upon horseshoe crabs spawning at the edge of Delaware Bay to fuel up during a 2,000 mile migration. Red Knot numbers are already declining—and global warming could speed the decline by altering the timing of the Red Knot's migration, or the timing of Horseshoe Crab spawning, reducing the availability of food.

The Delaware Bay: Reduced Numbers of Migratory Birds

The Delaware Bay is one of the most important stopovers for migratory birds as they travel between their winter and summer habitats. Every year, 1.5 million shorebirds stop at Cape May Point alone to refuel before continuing their long flight.[125]

The Red Knot is one of the most amazing birds that stop at the Delaware Bay. The bird flies more than 2,000 miles while migrating between its winter home in South America and its summer habitat in the Arctic.[126] The Red Knot is one of the most ambitious species of migratory birds on earth.

Red Knots and other migratory birds time their arrival at the Delaware Bay to coincide with the spawning of the horseshoe crab, which provides a plentiful food source.[127]

However, global warming is altering the timing of migration for birds across the world – just as it is causing earlier springs and warmer winters. Altered timing of migration – or alternatively, altered timing of horseshoe crab spawning – could cause serious problems for the Red Knot and other migratory bird species that depend on Delaware Bay.[128] If the birds no longer arrive at the correct time, it could limit their food supply and contribute to the decline of the species. For example, a mismatch of this kind between Pied Flycatchers and mosquito populations in the Netherlands has led to a 90 percent decline in some populations of these birds over the last two decades.[129]

Red Knot numbers are already in decline. Winter populations in South America appear to have dropped by more than 50 percent from the mid-1980s to 2003.[130]

In addition to altered migration timing, rising sea levels could reduce the availability of coastal wetland habitat for migratory birds and horseshoe crabs. Rising seas are likely to inundate marshes faster than they can move inland, and the presence of human development is likely to "squeeze" many areas of habitat out of existence.[131] One projection foresees a 57 percent decline in mud-flat habitat in the Delaware Bay if temperatures rise in the range of 3° F over the next century.[132]

Similar shifts in habitat and timing of ecosystem events across New Jersey put dozens of species at risk. The New Jersey Audubon Society estimates that global warming could eliminate at least 37 species of birds from New Jersey, including the already threatened Savannah Sparrow, Vesper Sparrow and Bobolink.[133]

Worldwide, the World Wildlife Fund estimates that "unchecked climate change could force up to 72 per cent of bird species in some areas into extinction."[134]

The Pinelands: More Attacks from the Southern Pine Beetle

The New Jersey Pinelands is one of the most unique ecosystems in America. The acidic soil and unique climate of the Pinelands host a rare and vibrant community of plants, including pitch pines, orchids, carnivorous pitcher plants, and wild blueberries and cranberries.[135]

Because major residential and commercial development has not impacted the area as much as in other parts of New Jersey, this rare stretch of 1 million acres of forests, small towns, small farms and wetlands remains preserved today. In 1978, Congress designated the Pinelands a United States Biosphere Reserve, and the area is managed under special land use rules by the Pinelands Commission, a special regulatory body created by the state government.

The Pinelands is home to more than 80 species classified as endangered in New Jersey, and more than 60 species classified as threatened.[136]

Many of the plants living in the Pinelands are at their extreme southern range.[137] These species are likely to decline in the Pinelands in response to climate change, as

Photo: David Olah

New Jersey Pinelands

their habitable range shifts northward out of the Pinelands region. For example, the U.S. Forest Service predicts that New Jersey's forests of Maple, Beech and Birch are likely to be replaced by forests more likely to contain Oak and Hickory trees.[138]

Species worldwide are shifting northward as the climate warms. In the last half of the 20th century, 1,700 plant, animal and insect species worldwide shifted toward the earth's poles at an average rate of about 4 miles per decade.[139]

Over time, global warming will shift the range of plants and animals that inhabit the Pinelands. The return of the Southern Pine Beetle to the Pinelands provides an example of the type of events that are likely to become more common in a future of global warming.

Photo: J.R. Baker & S.B. Bambara, North Carolina State University, www.forestryimages.org

Global warming could speed the return of the Southern Pine Beetle, seen here infesting the bark of a pine tree, in the coming years.

Until the New Jersey Division of Parks and Forestry discovered an infestation in 2001, no one had seen a Southern Pine Beetle in New Jersey for more than 60 years.[140] The Southern Pine Beetle is extremely destructive. After attacking a tree, the beetles burrow inside and lay eggs, often killing the tree within 3 to 4 months.[141]

By 2003, more than 2,000 acres of forest in southern New Jersey, including areas in the Pinelands, had been infested.[142] As the climate warms, and the habitable range of the pine beetle moves northward, wider beetle infestations could occur.

The Southern Pine Beetle is just one part of a series of changes that could signal a major change in the types of tree species that are able to grow in the Pinelands. Facilitated by beetle infestation and other attacks, the primary species of trees in the Pinelands could shift toward those normally found further south, like Loblolly Pine.

However, habitat fragmentation could prevent species from migrating north successfully and thus reduce their populations.[143] As a result of shrinking habitat caused by global warming, the Intergovernmental Panel on Climate Change estimates that 20 percent to 30 percent of species assessed so far worldwide will be at increased risk of extinction if global average temperatures rise more than 2.7 to 4.5° F. Above this temperature range, scientists expect "major changes in ecosystem structure and function, species' ecological interactions, and species' geographic ranges, with predominantly negative consequences for biodiversity."[144]

Responding to Global Warming

Global warming threatens to drastically change New Jersey. The first wave of those changes already appears to be taking place, with rising sea level, more heat waves, altered ranges of species like the Southern Pine Beetle, more frequent severe storms and more drought – possibly acting as a harbinger of greater changes yet to come.

The good news is that there is still time to prevent the worst impacts of global warming. New Jersey has the tools to reduce our global warming pollution and at the same time provide sound leadership for the rest of America and the world.

What the World Must Do

The severity of the likely impacts of global warming depends on how much global warming pollution the world emits in the years to come. If the world continues to burn fossil fuels at an ever-increasing rate, temperatures are likely to rise dramatically, causing severe and irrevocable damage to the world's ecosystems and its people.

But if we begin to reduce emissions now —and achieve steep reductions in global warming pollution in the years ahead – we can still avoid the worst impacts of global warming.

The European Union and others have come to accept a 3.6° F (2° C) rise in global average temperatures over pre-industrial levels as a rough threshold beyond which dangerous impacts from global warming will become inevitable.[145] Even if the rise in temperatures is held below 3.6° F, global warming will have significant – and in some places, severe – impacts. But beyond 3.6° F, the impacts of global warming become much more severe, including:

- Eventual loss of the Greenland ice sheet, triggering a sea-level rise of 7 meters over the next millennium (and possibly much faster)[146];
- A further increase in the intensity of hurricanes;
- Loss of 97 percent of the world's coral reefs;
- Displacement of tens of millions of people due to sea level rise;
- Total loss of Arctic summer sea ice;

- Expansion of insect-borne disease;
- Greater risk of positive feedback effects – such as the release of methane stored in permafrost – that could lead to even greater warming in the future.[147]

At temperature increases of 5.4 to 7.2° F (3 to 4° C), far more dramatic shifts would take place, including all of the above changes, plus:

- Increased potential for melting of the West Antarctic ice sheet, triggering an additional 5 to 6 meter rise in sea level;
- Major crop failures in many parts of the world;
- Extreme disruptions to ecosystems. [148]

Science suggests that, to have a reasonable chance of keeping global temperature rise below 3.6°F, the world must stabilize concentrations of global warming pollutants at or below 450 parts per million (ppm) carbon dioxide-equivalent. Even by achieving this stabilization level, the probability of keeping temperature rise below 3.6° F is about 50-50.[149] Thus, reducing global warming emissions sufficient to maintain global warming pollutant concentrations at or below 450 ppm is the minimum action necessary, as indicated by current science, to prevent dangerous, human-caused climate change.[150]

To stabilize greenhouse gas concentrations at or below 450 ppm, the world must stop the growth in carbon dioxide emissions by approximately the end of this decade, reduce emissions to 1990 levels by the 2030s, and reduce emissions by one third below 1990 levels by 2050.[151]

The United States, as the world's leading emitter of global warming pollutants (and the last Western industrialized country, other than Australia, to make a national commitment to reduce global warming emissions), has a disproportionate responsibility to achieve emission reductions. To do its "fair share" to reduce emissions, the United States must:

- stabilize emissions at or below today's levels by the end of this decade
- reduce emissions by at least 15 to 20 percent below today's levels by 2020, and
- reduce emissions by at least 80 percent by 2050.

These reduction levels assume similarly aggressive efforts to reduce emissions by other Western countries, along with action by developing nations such as China and India. In other words, should the United States fail to achieve global warming emission reductions at or beyond these levels, the chances of preventing dangerous, human-caused global warming will be much reduced.

Photo: Art Wilson / ACU

The Jersey-Atlantic wind farm in Atlantic City is capable of producing enough electricity to supply 2,500 homes—without emitting global warming pollution.

What New Jersey Must Do

With the Bush administration strongly resisting any serious efforts to reduce global warming pollution, New Jersey has joined with several other states to take strong action against global warming on its own. Among those actions, New Jersey has:

- Created goals to cut New Jersey's global warming emissions to 1990 levels by 2020 and 80 percent below current levels by 2050 by executive order;
- Joined 10 northeastern states – from Maine to Maryland – to create a cap-and-trade program to cap carbon dioxide emissions from power plants starting in 2009 and reduce emissions by 10 percent by 2019. Several western states are considering a similar program;
- Along with 10 other states, adopted standards to reduce global warming emissions from cars and light trucks; and
- Committed to obtain 20 percent of its electricity from clean, renewable sources of energy by 2020 and developed effective energy efficiency programs for electricity and natural gas use.

While these actions are significant, there is much more that New Jersey should do to reduce its emissions of global warming pollution and to set a positive example for other states and the nation in the fight against global warming. For example:

- California has enacted the nation's first statewide mandatory cap on global warming pollution, committing to reduce its global warming emissions to below 1990 levels by 2020.
- Momentum has increased in Washington, D.C. to develop a national response to global warming. A variety of proposals are now circulating in Congress to address the problem, with the best proposals requiring emissions reductions by 80 percent below 1990 levels by 2050.

Policy Recommendations

New Jersey should take deep and decisive action to reduce global warming pollution. Specifically, the state should:

Establish a mandatory cap on global warming pollution.

- The cap should reduce New Jersey's total global warming pollution by 20 percent by 2020 and at least 80 percent by 2050. It should cover all sectors of New Jersey's economy and require legally binding emission reductions.

Create a long-term global warming action plan, aimed at reaching more than 80 percent reduction in global warming pollution by mid-century, including the following policies:

- Prohibiting the construction of any new coal-fired power plants in New Jersey.
- Requiring all electricity imported to New Jersey from the regional electricity grid to meet state emissions standards.
- Maximizing New Jersey's energy efficiency potential, including implementation of an energy efficiency standards for public utilities to reduce statewide electricity and natural gas consumption, energy efficiency standards for appliances and buildings, and expansion of Combined Heat and Power (CHP) and demand-response initiatives.
- Renewing and doubling funding for New Jersey's Clean Energy Program

and establishing a goal for homegrown clean energy generation for the year 2050.

- Developing wind power off New Jersey's coast.
- Requiring developers to provide solar energy as an option for all new homeowners.
- Maximizing New Jersey's fuel efficiency potential, including requiring the sale of energy-saving tires, implementing pay-as-you-drive automobile insurance and creating financial incentives for purchasers of the most fuel efficient vehicles and disincentives for the worst gas guzzlers.
- Reducing vehicle miles traveled in New Jersey, including requiring mandatory ride reduction programs for large employers, restraining exurban sprawl, investing in mass transit expansion, and improving freight rail infrastructure.
- Establishing a low-carbon fuel standard.

Call on federal leaders to:

- Establish a national cap on global warming emissions. The cap should reduce the country's total global warming emissions by 15 to 20 percent by 2020 and 80 percent by 2050 and should prohibit the grandfathering of the worst global warming emitters, including fossil-fuel burning power plants.
- Increase federal fuel efficiency standards for cars and trucks to 40 miles per gallon within the next 10 years.
- Establish a federal renewable electricity standard requiring 20 of the nation's electricity to come from clean, renewable energy like wind and solar by the year 2020.

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