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Climate Change in Baltimore

Baltimore is the largest city in the state of Maryland with over 600,000 people in the city, and 2.7 million in the metropolis (US Census Bureau). 63.7% of people who live in the city are black or African American, which is 50% over the national average and the city also has a large proportion of families under the poverty level (US Census Bureau). However, Baltimore also has some very high income, majority white neighborhoods, along with very expensive private schools. This disparity sometimes causes racial and socioeconomic tension, as seen in the Freddie Gray murder and the protests and riots that followed. Baltimore also has important historical significance; it was one of the first cities colonized in the country, and the Battle of Fort McHenry, where Francis Scott Key wrote the Star Spangled Banner during the War of 1812. Finally, Maryland has a very diverse environment, from beaches on the Eastern Shore, to farmland, to the Appalachian Mountains, to forests, to cities, to the Chesapeake Bay.

The Baltimore Customs House meteorological station, located in downtown Baltimore, has been collecting data on the weather since 1893. This collection of data on daily temperatures and precipitation allows people to determine the long-term weather patterns, or the climate, and having data spanning over one hundred years allows people to analyze the change in the climate. My analysis of temperature change in Baltimore using the data collected by the customs house revealed that both the maximum and minimum temperatures have significantly increased in the past 123 years. This increase in temperature has had, and will continue to have, many negative effects on Baltimore.

The change in maximum temperatures was determined by selecting the highest temperature recorded in every month, plotting each point, then using a linear regression to determine the extent to which the maximum temperatures have changed (Figure 1). To calculate the change in minimum temperatures, the same process was employed using the lowest temperature recorded from each month (Figure 2). The maximum temperatures increased by about 0.02 °C every year with a p-value of 0.0056, which is much lower than the critical value of 0.05, meaning the increase was signifiantly significant. The minimum temperatures also increased by about 0.02 °C every year with a p-value of 0.0045. This means that over the 123 years the station was collecting temperatures, both the minimum and maximum temperatures increased by about 2.5 °C, or 4.5 °F. When the maximum and minimum temperatures were isolated by month, the p-value decreased even more, meaning the increase in temperature is even more significant. The maximum and minimum temperatures in July increased by over 0.02 °C per year with p-values 3.17 x10^-11 and 2 x 10^-16, respectively, meaning the cool days in July are becoming less cool, and the hot days are becoming even hotter (Figures 3, 4). For February, both the maximum and minimum temperatures have increased by about 0.03 °C a year, which is even greater of an increase than July, through the p-values were slightly lower (Figures 5, 6). This means that while the summers are getting hotter, the winters are warming just as much or more.

One major impact climate change could have on Baltimore is the increase in buildings using air condtiotioners. Air conditioning accounts for about 6% of all electricity produced in the US, and that energy causes over 250 billion pounds of carbon dioxide to be released into the atmosphere every year (U.S. Department of Energy). The maximum temperatures in July have increased by about 3 °C (5.5 °F) since the Baltimore customs house started collecting data. It is already uncomfortably hot in Baltimore in the summer, and if the maximum temperatures continue to rise, it will be unbearable to live without AC. The number of buildings with AC will increase, and the amount of energy it takes to cool down the building will increase. One study in Mexico found that for every day with a mean temperature over 90 °F, the electricity consumption for that month increased 3.2% (Davis & Gertler 2015). Also, while air conditioners are no longer allowed to emit Chlorofluorocarbons (CFCs), a compound that depletes the ozone layer, many still release Hydrochlorofluorocarbons (HCFCs), a very similar compound with almost the exact same effect (SEPA). Both the increase of Carbon Dioxide in the atmosphere and HCFCs depleting the ozone layer will lead to a increase in temperatures, leading to an increase in air conditioner use, creating a dangerous positive feedback loop.

One danger of climate change specific to Baltimore is the impact of warming on the Chesepeake Bay. Many different studies have estimated that the sea level around Maryland could rise a foot by 2050, which already puts parts of downtown Baltimore, including the Inner Harbor, a popular tourist destination, at risk for flooding (Climate Change Maryland). Warming could also have devastating effects on the ecology of the bay. The change in temperatures has already been shown to cause increase in algal blooms, which cause hypoxic zones, areas with low levels of oxygen, when they die and the bacteria use up the dissolved oxygen decomposing them (Najjar et al. 2010; NOAA). One study also found that as water temperatures increase, phytoplankton's respiration increases quickly, while photosynthesis increases much slower (Lomas et al. 2002). This also creates a net decrease in disolved oxygen in the water and increases the carbon dioxide levels. These problems combine to form bottom-layer hypoxia, where dissolved oxygen decreases with depth (Keister & Houde & Breitburg 2000), harming an essential Baltimore industry- shellfish.

Maryland is known for its blue crabs, and in 2014 alone, almost 25 million lbs of blue crab were harvested in Maryland (Maryland State Archives). Maryland's seafood industry contributes $600 million to the economy every year; along with the blue crab the three biggest contributors are striped bass, eastern oysters, and clams (Maryland State Archives). Bottom-layer hypoxia in the Chesapeake

Bay severely impacts crabs, oysters, and clams since they live on the sea floor, and the larvae of striped bass. A study from 2003 found that 50% of striped bass and up to 75% of crabs in the Chesapeake Bay are exposed to hypoxic environments, and the area of hypoxic zones have increased since then (EPA 2003). Hypoxic zones seriously diminish striped bass's swimming abilities, but even levels of dissolved oxygen slightly above the hypoxic threshhold can still stunt the growth of developing bass (Wannamaker & Rice 2000). Another study found that the mortality rate of oysters is significantly higher at greater depths due to stratified levels of dissolved oxygen (Lenihan & Peterson 1998). If climate change continues to increase the amount of hypoxia in the Chesapeake Bay, the seafood industry will incur large losses.

Some people argue that increased water temperatures will lengthen fish and crab growing seasons and decrease winter mortality of some species, increasing the productivity of the seafood industry (Najjar et al. 2010). While it is true that many species in the Bay would initially benefit from warmer temperatures, some species of clams, bass, and perch that need cooler water will be confined to smaller habitats and be unable to handle the summer temperatures (Najjar et al. 2010). Having an increase in the popultaion of some organisms and a decrease in others will most likely imbalance the food web and end up in a long term decrease in seafood. Also, lengthening the seasons of different species could cause new overlap that didn't exist before. For example, the lobate ctenophore, a jellyfish found in the bay, will be abundant in the bay earlier than normal because of the rising temperatures, but it will now overlap with the early life stages of certain fish and shellfish it preys on (Najjar et al. 2010). This will decrease the number of those fish and shellfish that make it into adulthood. Increased temperatures also foster a larger number and variety of pathogens able to live in the Chesapeake Bay, increasing the chance that disease will spread throughout fish or shellfish (Najjar et al. 2010). Overall, when all factors are taken into consideration, increased temperatures are and will continue to be extremely harmful to Baltimore.

Works Cited

Climate Change Maryland. Science. (n.d.). Retrieved December 11, 2016, from http://climatechange.maryland.gov/science/

Davis, L. W., & Gertler, P. J. (2015). Contribution of air conditioning adoption to future energy use under global warming. *Proceedings of the National Academy of Sciences, 112*(19), 5962-5967. doi:10.1073/pnas.1423558112

Keister, J., Houde, E., & Breitburg, D. (2000). Effects of bottom-layer hypoxia on abundances and depth distributions of organisms in Patuxent River, Chesapeake Bay. *Marine Ecology Progress Series, 205*, 43-59. doi:10.3354/meps205043

Lenihan, H. S., & Peterson, C. H. (1998, February 1). How Habitat Degradation through Fishery Disturbance Enhances Impacts of Hypoxia on Oyster Reefs. *Ecological Applications, 8*(1), 128. doi:10.2307/2641316

MARYLAND AT A GLANCE. (n.d.). Retrieved December 11, 2016, from http://msa.maryland.gov/msa/mdmanual/01glance/html/seafoodp.html

Najjar, R. G., Pyke, C. R., Adams, M., Breitburg, D., Hershner, C., Kemp, M., . . . Wood, R. (2010, January 1). Potential climate-change impacts on the Chesapeake Bay. *Estuarine, Coastal and Shelf Science, 86*(1), 1-20. Retrieved December 11, 2016.

National Oceanic and Atmospheric Administration. (n.d.). Retrieved December 11, 2016, from http://www.noaa.gov/

NOAA's National Ocean Service Education: Estuaries. (n.d.). Retrieved December 11, 2016, from http://oceanservice.noaa.gov/education/kits/estuaries/media/supp_estuar09b_eutro.html

SEPA. Hydrochlorofluorocarbons (HCFCs). (n.d.). Retrieved December 13, 2016, from http://apps.sepa.org.uk/spripa/Pages/SubstanceInformation.aspx?pid=120

UNITED STATES QuickFacts from the US Census Bureau. (n.d.). Retrieved December 12, 2016, from http://www.bing.com/cr?IG=BC507D895E0047B881FD6108A304A660&CID=0CE70C0665DB6A771C4005ED64EA6B73&rd=1&h=E3pq-CFNDYqhdrXj3fWZttflUguOvjNHEToscPxm7D4&v=1&r=http://www.census.gov/quickfacts/table/PST045214/00&p=DevEx,5083.1

US Department of Energy. (n.d.). Air Conditioning. Retrieved December 11, 2016, from http://www.energy.gov/energysaver/air-conditioning

USA, EPA. (2003). *Ambient water quality criteria for dissolved oxygen, water clarity and chlorophyll a for Chesapeake Bay and its tidal tributaries*. Anapolis, MD: U.S. Environmental Protection Agency, Region III, Chesapeake Bay Program Office.

Wannamaker, C. M., & Rice, J. A. (2000, June 28). Effects of hypoxia on movements and behavior of selected estuarine organisms from the southeastern United States. *Journal of Experimental Marine Biology and Ecology, 249*(2), 145-163. doi:10.1016/s0022-0981(00)00160-x

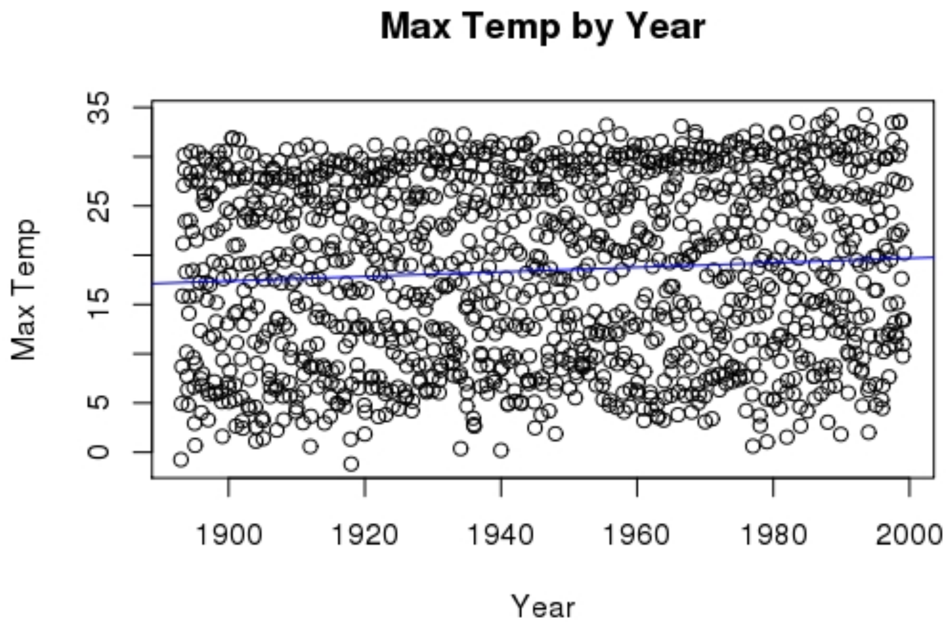

Figure 1- The maximum temperatures of each month

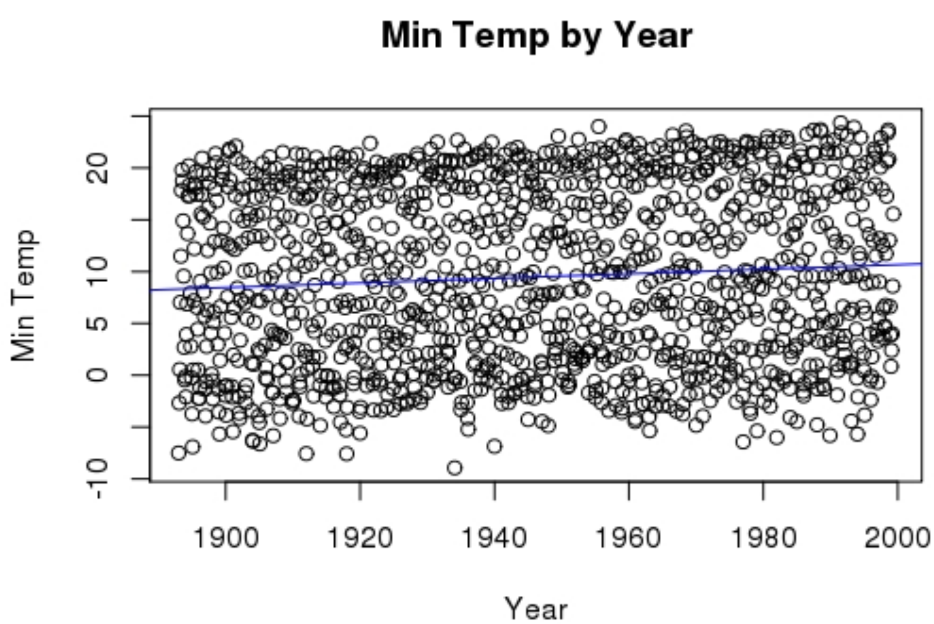

Figure 2- The minimum temperatures of each month

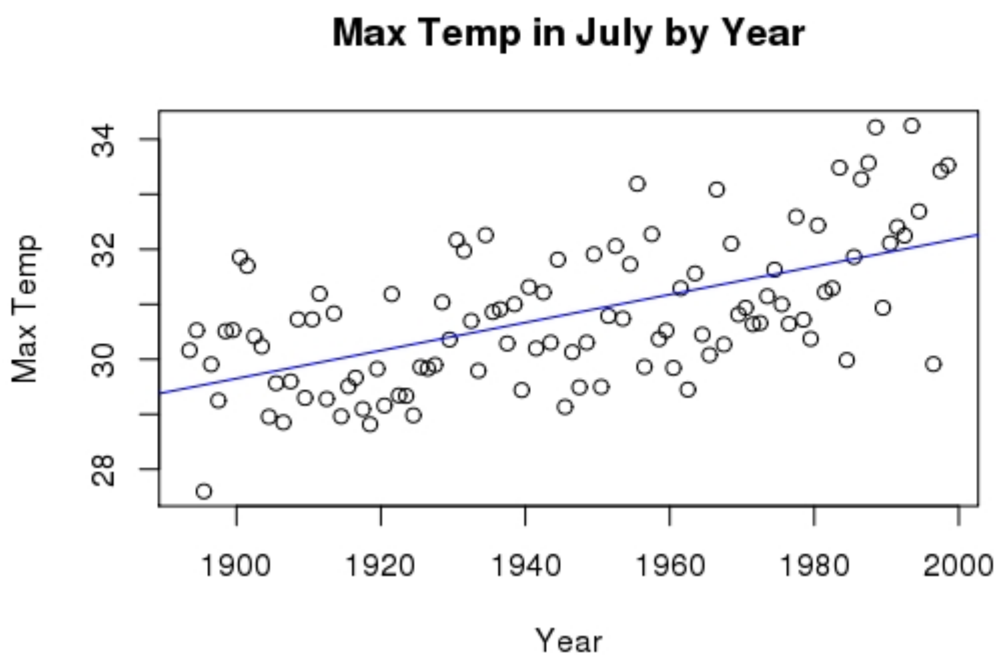

Figure 3- The maximum temperatures of every July

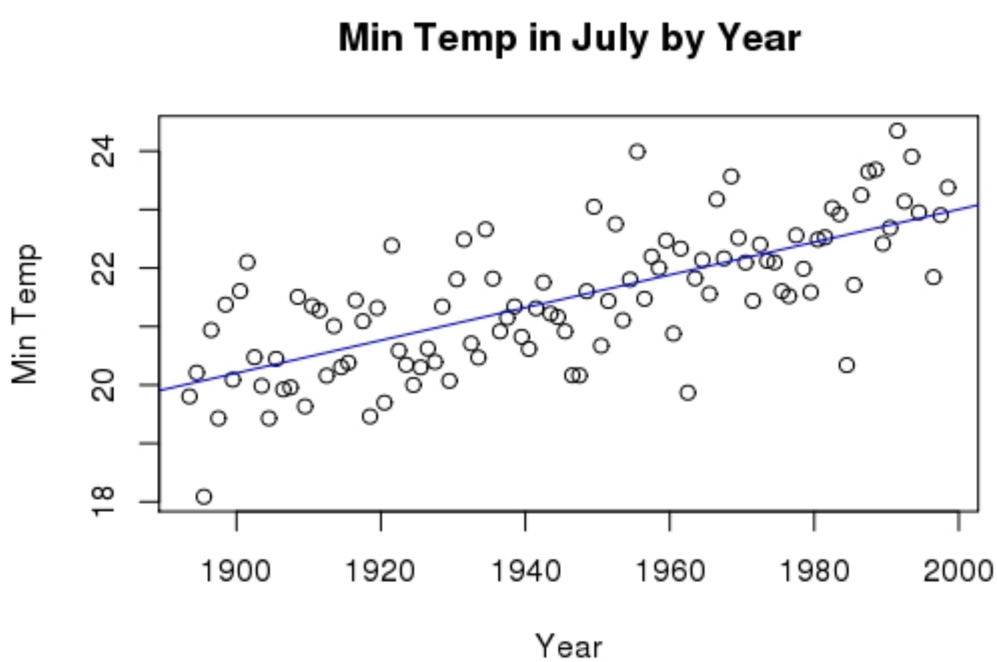

Figure 4- The minimum temperatures of every July

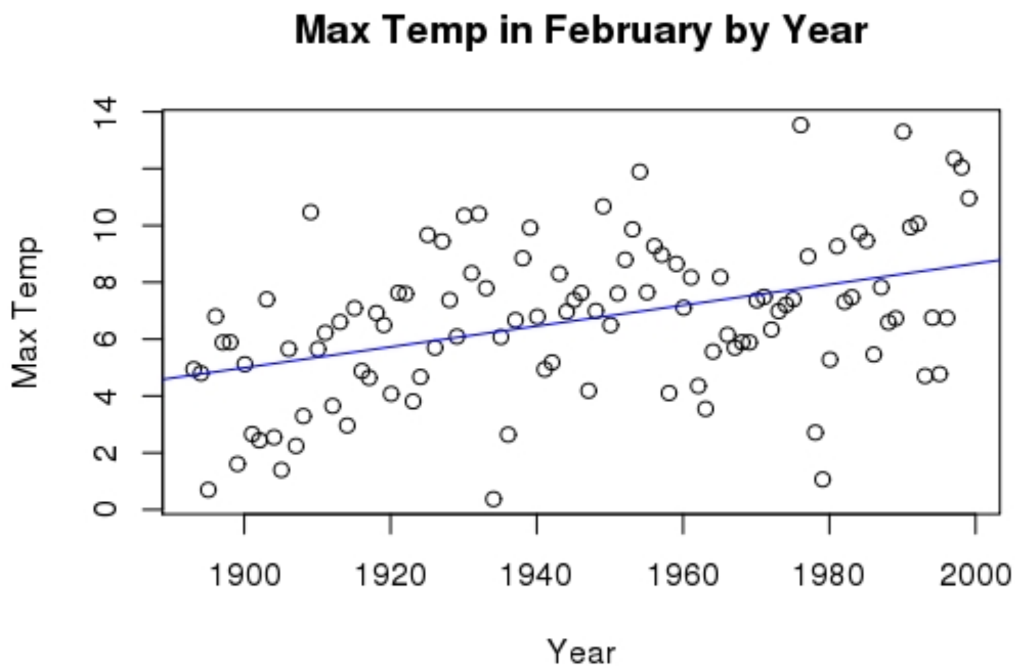

Figure 5- The maximum temperatures of every February

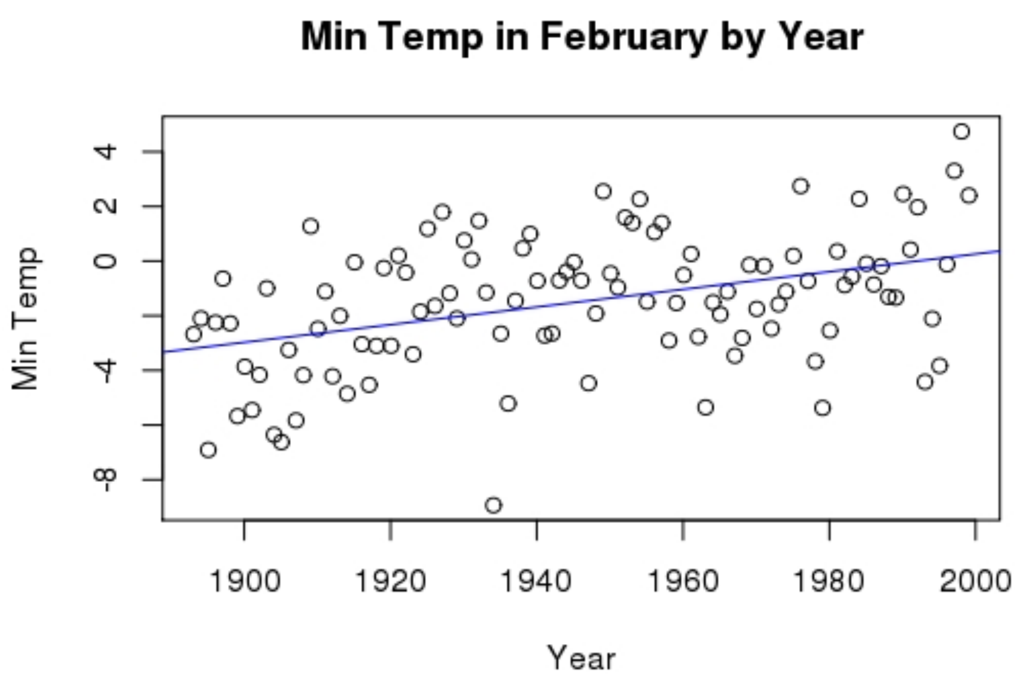

Figure 6- The minimum temperatures of every February