Extreme Weather and its Impacts on Human Civilizations:

An In-Depth Investigation of Causes and Effects

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Abstract

Extreme weather has impacted humanity since creation and is an important topic that deserves examination. In this thesis, the main event that is presented and analyzed is the extreme haze that clouded much of China’s skies in 2013. Further, the impacts this major event had on people, including changes in population movement, death/injury rate, and changes in atmospheric chemistry due to the high concentration of particulates are discussed. Subsequent examples that will be explored include Hurricane Katrina and the eruption of Mt. St. Helens. The main contention of this thesis is that the effects extreme weather has on human civilization are broader and more varied than it seems after first consideration and should be evaluated on a deeper level.

Extreme Weather and its Impacts on Human Civilizations:

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Throughout the course of human history, extreme weather has played a significant role in the movement, lifestyle, and decisions human beings have made. The impact extreme weather has had is an important issue that influences much of what is seen today in the world. Further, isolated extreme weather events have been known to displace entire streets, neighborhoods, and even cities, as well as lead to alterations in normal human physiology. For example, the severe haze event that occurred over China in 2013 triggered the onset of widespread respiratory illness and atmospheric changes in local communities. While many people already accept that weather events such as tornadoes, hurricanes, tsunamis, earthquakes, avalanches, etc. are extreme, it is not as quickly realized that various extreme weather events impact people in more pervasive ways than may be thought of initially.

Within this thesis, an in-depth analysis of the extreme haze that affected China in 2013 will be analyzed, including its atmospheric and human impacts. Alongside this main case, two supplementary events will be evaluated in support of the China case. The first case will be a study of the effects Hurricane Katrina had on the people living in the New Orleans area. The second case will be an in-depth consideration of the Mt. St. Helens eruption and its impacts on the people near the eruption and the atmospheric impacts it had in multiple layers of Earth's atmosphere.

Definition of Extreme Weather as it Will be Used in this Thesis

When the general population thinks of extreme weather, what usually comes to mind are locally-destructive events such as tornadoes, hurricanes, etc. However, it is frequently overlooked that extreme weather events do far more than impact easily visible areas of everyday life and Earth’s surface. Therefore, the definition of extreme weather for this thesis is as follows: any weather event, or its aftermath, that drastically alters human behavior or health. This dramatic change in behavior can include, but is not limited to, temporary population movement, injury, death, lifestyle change, atmospheric alteration, economic loss or hardship, or permanent population movement.

Overview of Some Effects Extreme Weather has had on Human Civilization

As stated previously, extreme weather has altered human civilization patterns for thousands of years. However, not all extreme weather events occur the same way, and some may have greater acute or long-term impacts than other weather events. For instance, a small tornado or in-line wind event in an empty field in Oklahoma will have a lesser effect on society than a tsunami that devastates an entire coastal village; impact clearly has a dependency on the population density of the affected area.

Population Movement

One of the ways that extreme weather has exerted its effects on people is by leading to the mass movement of people out of one area and into another. When Hurricane Katrina struck New Orleans and the surrounding area in 2005, thousands of people were forced out of their homes and had to find a new place to live until the waters subsided. However, even after the flood waters were no longer present, some people found themselves unable to return to their home due to extensive damage or insufficient funds. Therefore, temporary (and some permanent) migration was directly associated with the event of Hurricane Katrina and the lives of the people who once lived in New Orleans were permanently changed (Landry et al., 2007). Because of the dramatic impacts the hurricane had on the people of New Orleans, and particularly due to the wide range of effects that were observed during and after the event was over, Hurricane Katrina is classified as an extreme weather event based on the stated definition of extreme weather earlier in this thesis.

Death/Injury

Extreme weather frequently leads to the death or injury of the people caught in the path of the event. One of the main health concerns that resulted from the severe haze over China was the development of respiratory diseases, which were caused by the excess accumulation of $PM_{2.5}$ (particles in the air with a diameter of less than 2.5 μm) in the region (Liang, et al., 2015). While the individual economic burden as a result of the respiratory diseases is difficult to assess because of China's free public health care policy, the exposure to particulate pollution in the atmosphere affected people and altered their respiratory health for a long duration of time and lowered some people's quality of life. Depending on the type of extreme weather being discussed, death and/or injury can result, but usually if the event is severe enough, both of these tragedies follow.

Atmospheric Chemistry

Upon analysis of extreme weather events, it becomes clear that these events can cause drastic changes in atmospheric chemistry, which have serious implications depending on the extremity of the change. With the eruption of Mt. St. Helens, thousands of tons of volcanic ash were spewed into the upper layers of the atmosphere, disrupting the normal beneficial atmospheric chemistry that usually occurs there (Zhu et al., 2020). Eventually, the ash drifted back to the surface, causing respiratory problems and potentially other diseases. Additionally, while in the atmosphere, the particles blocked out a majority of the sunlight, halting some of the reactions that occur in the atmosphere and changing the temperature of the earth's surface down below (Langmann, 2013).

In 2013 with the severe haze over China, the atmospheric chemistry was impacted by the increased level of particulates in the atmosphere, particularly the $PM_{2.5}$. As the optical density of the haze increases, the amount of sunlight that can reach the earth's surface decreases, which can also reduce visibility in the region (Liang et al., 2015). With reduced sunlight, the light-dependent reactions occurring in the atmosphere lack the proper energy to proceed as normal, thus altering or lowering the percentage of successful reactions that can take place. For example, one light-dependent reaction that occurs in the atmosphere is the photodissociation of nitrogen dioxide (NO_2) into nitrogen monoxide (NO) and ozone (O_3); with lower amounts of sunlight available, this process would be less efficient and lack the necessary energy required for the reaction to proceed. A potential consequence of a decrease in the above reaction would be the depletion of ozone, which has serious implications for protecting people from the harmful ultraviolet (UV) light from the sun. Protection from the sun's harmful UV rays is important due to the rays' non-selective, complete carcinogenic effects, which can lead to the breaking of bonds in important biological molecules such as DNA and RNA (D'Orazio et al., 2013).

Extreme Weather of All Kinds Impacts People Around the Globe

Many people understand the fact that the initial "main event" of severe weather can be incredibly powerful and deadly. However, it is sometimes not just the easily visible effects from a weather event that carry serious implications for human life or health. There are times that chronic exposure to the aftermath of an extreme weather event can lead to severe health issues or impacts, even though an individual may not have been exposed to the main weather event. For instance, with the Mt. St. Helens eruption, a decrease in the ozone layer in the atmosphere was observed (Hobbs et al., 1982). Although many were not impacted by the blast itself, anyone living in the region was exposed to more of the sun's UV rays, which can lead to an increase in cancer over time. It is apparent then that surviving the initial storm or event does not mean that one is in the clear and precautions should be taken to educate oneself about potential harm of the aftermath.

Generally, when discussing various weather events happening around the world, people may easily disregard the weight of distant extreme weather events on others around the globe and proceed to live unaffected lives. However, the fact that some of these extreme weather instances displace or even kill thousands of people is something that should be critically considered. By looking at some specific examples, such as the extreme haze that covered portions of China in 2013, as well as the supplementary examples of Hurricane Katrina and the eruption of Mt. St. Helens, this thesis will explore and demonstrate the fact that human civilization is more broadly impacted by extreme weather than it may appear after first consideration. Figure 1 below shows the layout of the remainder of this thesis.

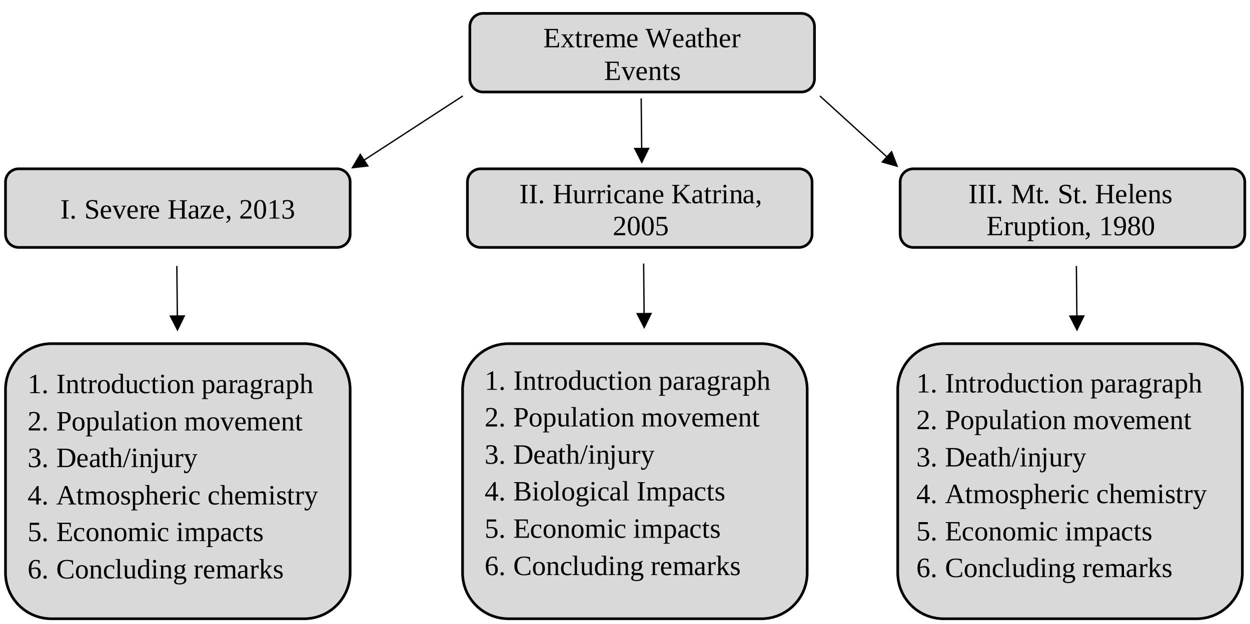

Figure 1. Layout of the Remainder of This Thesis. The first portion of this paper covers the severe haze event that occurred over much of China in 2013, followed by analysis of the effects Hurricane Katrina had on the New Orleans, Louisiana area, and concludes with a detailed look into the impacts of the 1980 Mt. St. Helens eruption in Washington.

Severe Haze Event – China, 2013

Beginning in January of 2013, a long-lasting and extreme episodic haze occurred over northern and eastern China, with downtown Beijing's $PM_{2.5}$ concentrations exceeding 75 $\mu g/m^3$ for 70% of the days in January (according to monitoring data from the Chinese Academy of Sciences) (Gao, et al., 2015). With such high concentrations of particulate matter in the atmosphere, as well as the imminent health concerns implicated with such a drastic change in environmental conditions, a deeper exploration of this particular Chinese severe haze event is warranted. Specifically, understanding the impacts this extreme event had on population movement, death or injury (which includes any potential health effects or concerns), atmospheric chemistry, and the economy of the most impacted regions will be important.

Population Movement

Although there is no data indicative of long-term or temporary population movement due to the severe haze event in 2013, it is possible that people with lung conditions or other health concerns moved out of the region for the duration of the event. While events such as Hurricane Katrina led to more localized damage and destruction, especially in New Orleans (905.98 km^2 and 1.386 million people), the extreme haze experienced by China in 2013 impacted a land area of 1.3 million km^2 and approximately 800 million people (Huang et al., 2014). Because the area of the event was so large and affected millions of people, and due to the commonality of haze events in China, it was unlikely there was a drastic population shift to evade the haze event. In order to prepare for or survive the haze, it is reasonable to speculate that more people remained home and protected themselves by staying indoors for the duration of the haze.

Death/Injury

As is expected when foreign chemicals are inhaled into the lungs, intake of pollutants can produce very harmful side effects in the body. During the severe event in 2013, the hourly $PM_{2.5}$ indexes were well above the upper limit of the Air Quality Index, and the visibility was so low that there were multiple instances of flights being cancelled, despite current technology that allows pilots to fly in the downgraded visibility (Qiongzhen et al., 2015).

In the month of January, which was when the severity of the haze was at a maximum, the mortality was estimated to be 690 people (95% confidence interval (CI): 490-890) (Gao et al., 2015). Concerning premature deaths, it is estimated that in Beijing alone, where the pollution was shown to be some of the worst across the country, there were approximately 725 premature deaths caused by haze, with an estimated 2,725 deaths (0.2008 deaths per 100,000 people in the population) across 12 different cities from January 10-31, 2013 (Gao et al., 2015). But while many families were impacted by the deaths of their loved ones, there are also many people who have survived, yet endured respiratory illnesses, both short and long term.

Exposure to $PM_{2.5}$, one of the main components of the extreme haze in the 2013 event, has been shown to lead to a variety of severe and unintended health impacts. Since $PM_{2.5}$ is smaller than many other types of particulate matter, it is able to deposit deeper into the tracheobronchial and alveolar regions of the lungs and wreak havoc on the respiratory system (Yin et al., 2017). Because of this, fine particulate matter such as $PM_{2.5}$ is considered more harmful than air pollutants with larger dimensions such as PM_{10} (particles in the air with a diameter of less than 10 μm) which cannot penetrate quite as deep into the respiratory system. Within the respiratory tract, $PM_{2.5}$ has been shown to be related to platelet activation and lung inflammation, both of which can lead to cardiovascular diseases and lung cancer (Yin et al., 2017). Aside from respiratory effects, particulate matter aggregates have been shown to cause both carcinogenic and non-carcinogenic effects in humans, which has led to many nations enacting air quality standards to help better the health of the people in their countries. In 2013, Beijing put into action the “Five-year Clean Air Action Plan (2013-2017),” which aimed to reduce the levels of $PM_{2.5}$ by 25% by the year 2017 (Yin et al., 2017). A chart with more detailed health effects caused by $PM_{2.5}$ is shown in Figure 2 below.

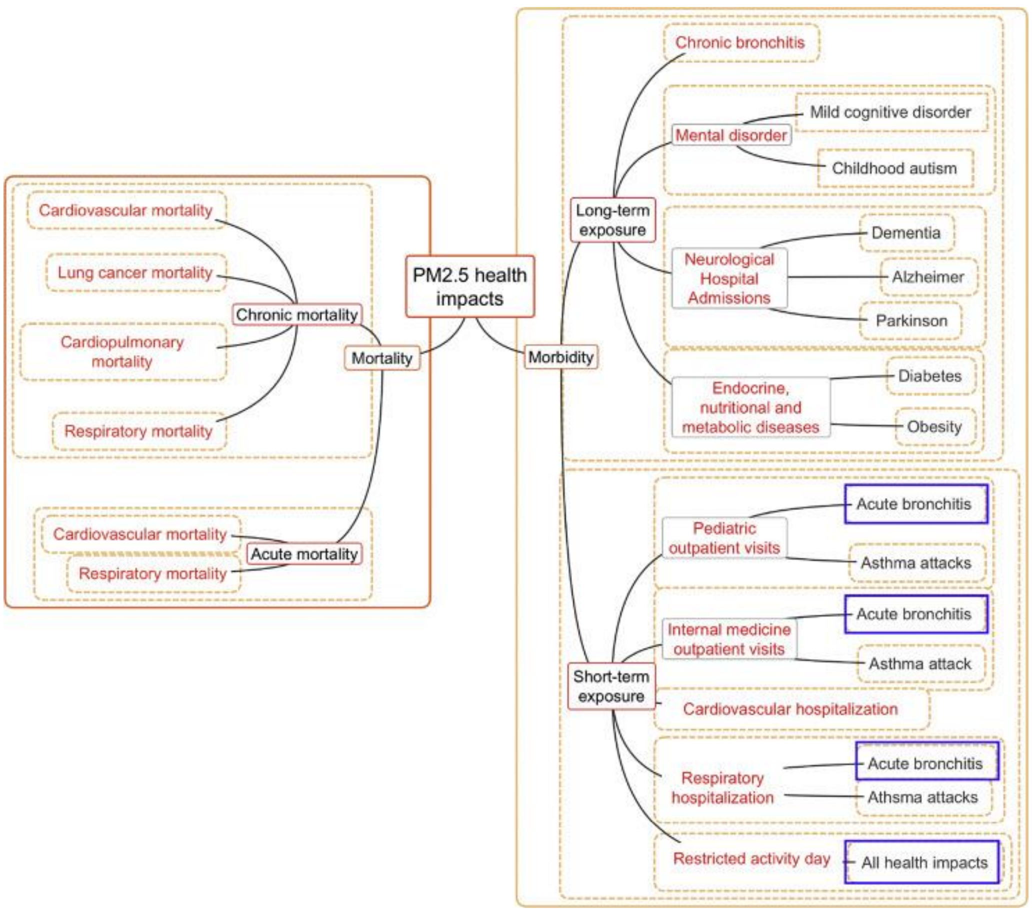

Figure 2. Known Health-Related Impacts of Exposure to $PM_{2.5}$. The left side of the diagram reveals mortality-related impacts, which emphasizes death-related conditions, while the right side of the diagram focuses on morbidity, which is more concerned with disease states rather than death (Yin et al., 2017). Used with permission.

Although many people may have an understanding that breathing in small particulates might be damaging to the lungs, the actual level of harm inflicted upon the human body from these small particles is commonly overlooked. Therefore, it is vital that haze, especially severe haze, be considered an extreme weather event as defined in the early paragraphs of this thesis due to the tendency to disregard the detrimental effects of these events on air quality and populations, even over a short period of time.

Atmospheric Chemistry

In general, haze can be attributed to larger-than-normal emissions of sulfur dioxide (SO_2), nitrogen oxides (NO_x) with varying numbers of oxygen atoms, volatile organic compounds (VOCs), and particulate matter (PM) sourced from many different activities such as industrial activity, public and private transportation via cars and buses, power plants, and the burning of biomass (Qiongzhen et al., 2015). Throughout China, coal is the major fuel source used for energy production and is also one of the more prominent sources of SO_2 emissions. Further, a recent increase in the number of motor vehicles being used throughout the country is the major contributor of the NO_x and PM pollution in some of the more urban areas, including Beijing (Qiongzhen et al., 2015).

Once the gases have entered the atmosphere, they undergo what is known as a gas-to-particle transformation, an event greatly important in the physical formation of the observed haze. Further, secondary ionic components such as NO_3^-, SO_4^{2-}, and NH_4^+, combined with organic matter, always increase during haze episodes and are the most common components in aerosols (around 75% of the total $PM_{2.5}$ mass) (Qiongzhen et al., 2015).

Over the course of one year, the leading contributor of haze pollution in China varies as the main energy source for the population changes. In the May-June and October-November months, considered to be the post-harvest months, the open-burning of biomass will lead to a significant increase in haze pollution, while coal combustion causes a rise in haze pollution in the winter months when people are using coal as a primary source of heat (Qiongzhen et al., 2015). Figure 3 below shows the percent sources of combustion-derived black carbon (BC) aerosol in three different regions in China during the 2013 severe haze event.

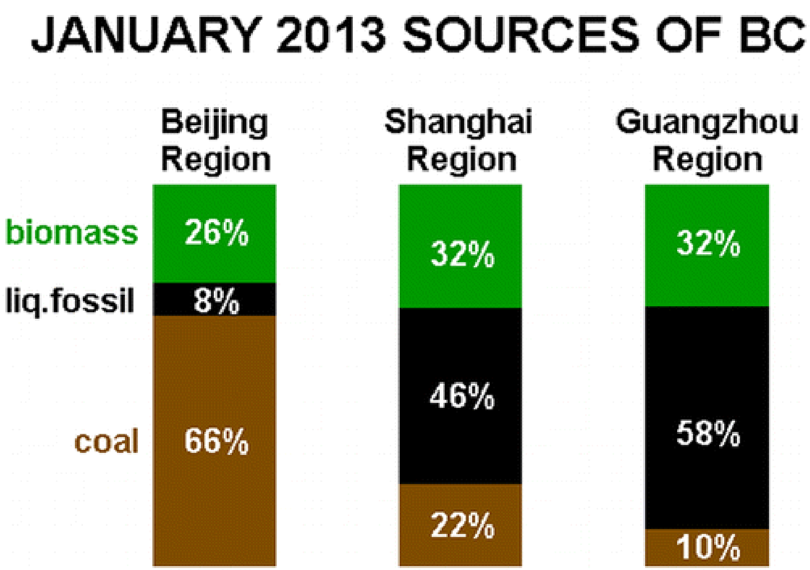

Figure 3. Sources of Combustion-Derived Black Carbon Aerosol in Various Regions in China. While the percent of biomass remains fairly constant across the various regions in China, the percent of coal and liquid fossil use varies amongst the three regions. Coal is observed to be the leading contributor of BC in the Beijing region, while liquid fossils are the leading source of BC in the Shanghai and Guangzhou regions (Andersson et al., 2015). Used with permission.

Because coal is a major contributor of BC in the winter months (Qiongzhen et al., 2015), it would be expected that Beijing had an especially high level of $PM_{2.5}$ in the atmosphere during the haze event since it utilized the most coal of the three regions in Figure 3. In 2015, researchers set out to determine the distributions of fine particulate matter throughout various cities and regions in China during the January 2013 haze event, including a region that contains Beijing called the Jing-Jin-Ji area. As anticipated, the Jing-Jin-Ji area contained the highest measured levels of $PM_{2.5}$, with levels measured at 195 ug/m^3 (Jiang et al., 2015). In fact, the Jing-Jin-Ji region contained the highest levels of all pollutants ($PM_{2.5}$, PM_{10}, SO_2, NO_2, and CO) except ozone (O_3). It is possible that due to the fact this haze event occurred in January, the high level of coal use in Beijing (based on Figure 3) caused the observed pollution to be far higher than the other regions tested (Jiang et al., 2015).

Particularly concerning Beijing, the capital of China and one of the largest metropolitan cities in the world, it has been shown that the haze was worse in this region than the rest of the country based on calculated $PM_{2.5}$ concentrations (Qiongzhen et al., 2015). Interestingly, there exists a trend showing that the more southern and central regions of Beijing experienced harsher haze conditions than the rest of the city (Du & Li., 2016). Based on a map of Beijing provided by researchers Du and Li, the northern districts of Beijing are considered to be ecological preservation areas, indicative that the population in these areas is less dense than the central parts of the city known as core areas. Because there are more people in the core areas of the city, there is an estimated increase in the number of pollution-emitting vehicles and factories, which adds to the formation of the haze through the conversion of pollution gases to aerosols, a potential internal contributor to the haze experienced in 2013 (Qiongzhen et al., 2015). This idea will be expanded upon in the following section concerning the increased economic impacts based on the denser population in the core regions of Beijing.

Economic Impacts

It can be assumed that with any dramatic increase in medical care and deaths due to extreme weather events, there is an associated rise in economic costs. Due to the haze deaths experienced in January of 2013, an estimated 180 million US dollars were lost, which was an astounding 0.76% of the gross domestic product (GDP) (Du & Li, 2016). Although much of China experienced the haze, Beijing, being the most populous city, experienced haze much worse than the rest of the country. Because of this, Du and Li conducted a case study on 16 different districts in Beijing and found that the ratios of economic cost due to the haze and GDP varied greatly across all 16 districts in Beijing (Du & Li, 2016). A map of the various regions in China that will be discussed in the rest of this section is shown in Figure 4 below.

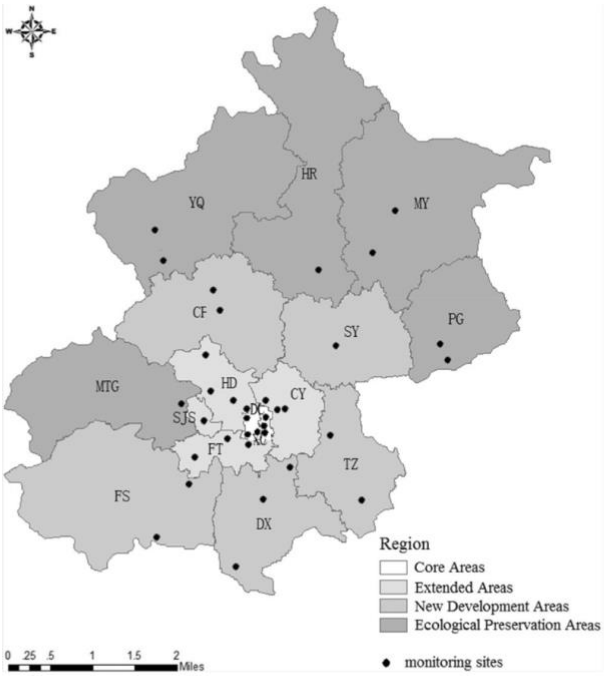

Figure 4. Labeled Regions of the City of Beijing for Discussion of Economic Loss. The above image depicts the 16 studied regions of Beijing, China, the capital of the country and the city that experienced haze worse than much of the rest of the country in the 2013 severe haze event (Du & Li, 2016). Used with permission.

In general, the highest economic loss occurred in the CY district (immediately East of the core areas), with a loss of about 35.72 million US dollars, followed immediately by the HD district, which lost around 26.33 million US dollars. On the opposite side of the spectrum, the smallest loss occurred in the YQ district (1.28 million US dollars), with other small losses occurring in the MTG, MY, and HR districts (2.07, 2.34, and 2.47 million US dollars, respectively) (Du & Li, 2016). As mentioned briefly in the atmospheric chemistry section above, it is possible that the reason the ecological preservation areas did not experience nearly as much economic loss is because there are not as many people as in the more central regions of the city.

With a lower population density comes decreased fatalities in these regions, lessening the economic burden experienced because of the deaths.

Aside from the economic costs of death and injury itself, such as funeral costs and medical bills, additional economic consequences indirectly caused by the haze itself exist as well. First, as a result of the unfortunate loss of life experienced in 2013, there are now fewer workers in the country who can help sustain or boost the GDP and stimulate the economy. Also, for all of those who were hospitalized or injured due to the haze, going in for work was not possible given the circumstances. Because of this, the economy experienced some loss while the thousands of affected people recovered from the side effects of the haze event.

Concluding Remarks – China, 2013

Although many extreme weather events are easily recognized by the general population as being severe and dangerous to humans, the haze that occurred in China in January of 2013 is not an event that may appear critically dangerous at first glance. The arguments presented here confirm the contention of this thesis and highlight why this severe haze has more serious implications than may first appear. The remaining pages of this thesis will discuss two weather events that many would likewise deem extreme and impactful, although some of the effects may be commonly overlooked.

Hurricane Katrina – New Orleans, Louisiana, 2005

In August of 2005, one of the deadliest natural disasters to strike the country hit the Southeastern United States. This weather event killed or injured thousands of people and left an estimated 81.2-billion-dollar path of destruction in its wake (Landry et al., 2007). Aside from the strong winds, torrential downpours and flooding from the waters of the Gulf of Mexico devastated the southeastern United States, especially New Orleans. Upon initial consideration of this extreme weather event, many people recognize the impacts that the flooding had on the population of New Orleans, as seen in Figure 5. However, many fail to realize the longer-term impacts this event had on people in New Orleans and the surrounding areas and environments.

Figure 5. Flooding Observed as a Result of Hurricane Katrina. The above map shows the city of New Orleans and the various regions of the city that were impacted by the floodwaters. The top of the image is closest to the Gulf of Mexico, which would explain why the flooding was the worst in these Northern locations. Also, the dots (where bodies were found) were concentrated in the spots where the flooding was the worst (Sharkey, 2007). Used with permission.

Population Movement

As Hurricane Katrina drove toward the Gulf Coast, millions of people found themselves in the path of the powerful hurricane. Due to the approaching storm, Alabama, Mississippi, and Louisiana issued evacuation orders for their residents, particularly for those residents closer to the coastline (Landry et al., 2007). Before Hurricane Katrina struck the coast, roughly one million people had evacuated New Orleans on August 27 and 28, 2005. However, even though many evacuated, about 70,000 residents remained in place. While some of those 70,000 individuals stayed in New Orleans by choice, most of them did not have a means of escape (Landry et al., 2007). Based on the data, it is safe to assume that pre-Hurricane Katrina migration was a largely successful effort that helped to save thousands of lives. However, after the storm had inflicted billions of dollars in damage, and destroyed or damaged tens of thousands of homes, many of those people who had evacuated were required to make a crucial decision about whether to return to a home that was destroyed or start a new life in a foreign location.

Although the pre-hurricane migration affected the population of New Orleans, it can be argued that the post-hurricane population shifts and changes more accurately show the true impacts Katrina had on the people in the Gulf Coast region. After the storm, between the months of August and November 2015, about a quarter million people lost their jobs, many of whom had also lost their homes. Further, of the roughly 117 hurricane-affected counties of the Gulf Coast, 40 of them declined in population from July 1, 2005, to January 1, 2006 (Landry et al., 2007). New Orleans, being one of the more populated counties affected by Hurricane Katrina, experienced the steepest population decline, among urban areas such as Mobile, Alabama (Landry et al., 2007).

Death/Injury

As one of the deadliest and costliest natural disasters in American history, Hurricane Katrina brought an unprecedented number of casualties. Researchers determined after the event that there were 971 people who died directly because of the hurricane in Louisiana, with another 15 having died in other states (Brunkard et al., 2013). Among the most common causes of death were drowning due to the floodwaters (40%), injury and trauma (25%), and heart conditions (11%). Further, of the people who died, 49% were 75 years old and older, 53% were men, 51% were black, and 42% were white (Brunkard et al., 2013).

Concerning nonfatal injuries, the number of hospitalizations were much higher than the reported number of deaths, which is generally expected with extreme weather events. To account for the number of sustained injuries as a result of Hurricane Katrina, researchers collected surveillance data from eight hospitals and 20 non-hospital acute medical care treatment centers in the New Orleans area. In data collected from September 8 to October 14, 2005, there were 7,543 injury-related visits for medical care. Interestingly, residents aged between 25 and 54 sustained 50% of all reported injuries, those older than 65 accounted for 11%, and children under 15 years old accounted for 9% (Sullivent III et al., 2006). Among some of the most common injuries that were sustained as a result of the hurricane or its aftermath included, but are not limited to, cut/pierce/stab wounds (20%), a fall (20%), struck/against/crushed by an object (11%), a bite/sting (9%), and a motor vehicle crash (8%) (Sullivent III et al., 2006).

Upon analysis of the fatalities, as well as the nonfatal injuries, an interesting statistic presented itself. It was noted that 49% of deaths were people older than 75. Yet, the age group that sustained the most injuries were between 25 and 54 years old. There are a few possibilities that could be causing this discrepancy. First, it is possible that the older residents, upon sustaining an injury, were not able to recover as effectively and, therefore, were more likely to die as a result of their injuries. Another potential explanation is that more elderly residents sustained more severe injuries in the first place and, thus, were less likely to survive the incident. Last, it is also possible that younger civilians were more likely to return to their homes to salvage belongings or make repairs and, thus, sustained more non-fatal injuries than the older residents. Although none of the suggested reasons for the discrepancy are certain, all three are plausible explanations for the statistics observed because of Hurricane Katrina and its aftermath.

Biological Impacts

Due to their intense winds, rainfall, and destruction, hurricanes are known to stir up a great amount of sediment and debris as they move through a region. Because of this, the biological ecosystem of affected areas can be altered, whether temporarily or permanently. Therefore, instead of exploring the atmospheric conditions of Hurricane Katrina, which are similar across the board for all hurricanes, this section will analyze the biological impacts Katrina had on various ecosystems in the Gulf Coast region due to its intense flooding and inflicted damage.

About one month after Hurricane Katrina, Hurricane Rita also struck the coastline immediately west of Katrina's path. Once both hurricanes had inflicted their damage, surveyors collected data about chemical contaminants in oyster tissue on September 29 and October 10, 2005, to analyze the impacts Katrina and Rita had on the oyster population, which had been monitored for years prior to the hurricanes (Johnson et al., 2009).

Overall, researchers found that there were elevated levels of metals observed in the oyster tissue post-hurricane when compared to the 20-year historical records for most of the tested oysters at the sites of interest. In particular, there were significantly-elevated levels of nickel and lead in the oyster tissue. Further, the data showed that oysters tested in 76% of the sites contained nickel, lead, and copper levels that were higher than the 20-year site median for oyster tissue concentrations of these metals (Johnson et al., 2009). Interestingly, 19% of the measured metal concentrations actually set national record highs and exceeded the 20-year oyster record for nickel, lead, and copper at six, four, and three of the sites, respectively (Johnson et al., 2009). Figure 6 below shows the sites of interest, the pre-hurricane levels of each metal, and the post-hurricane measured concentrations of each metal as found in the oyster tissue.

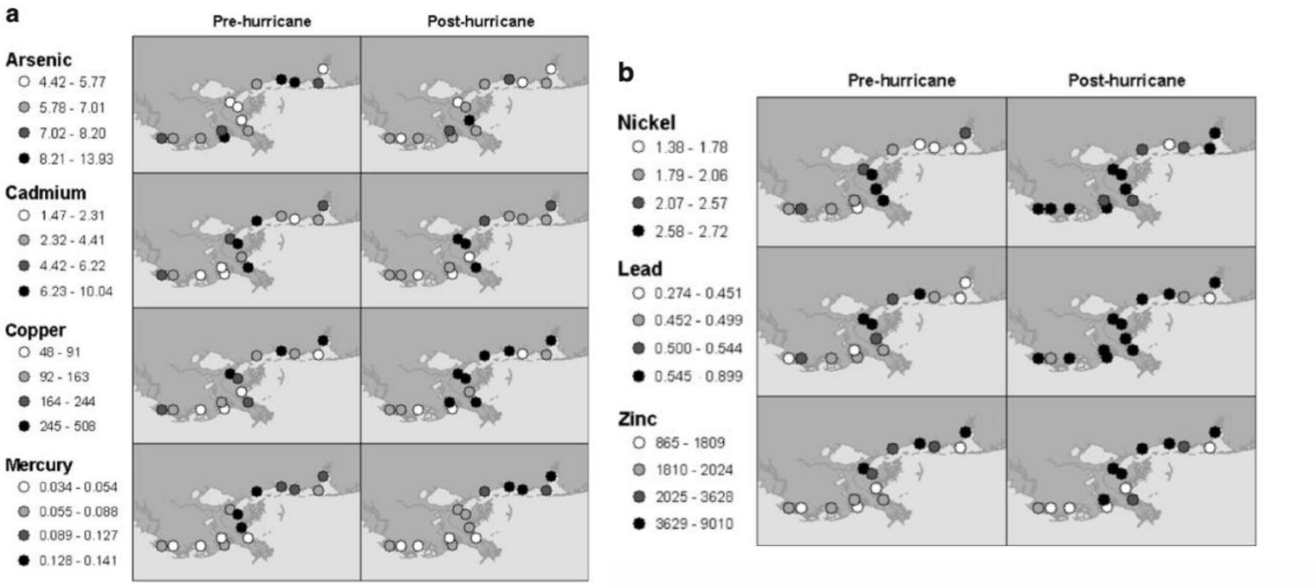

Figure 6. Pre-Hurricane and Post-Hurricane Metal Concentrations as Found in Oyster Tissue at Various Locations Along the Gulf Coast. Panels A and B of the above figure show the metal contaminant distributions and concentrations (ppm) for various metals both before and after Hurricanes Katrina and Rita struck the Gulf Coast region. The data indicate that metal contaminant distribution increased for all metals, whether by a small or large amount, at most of the testing sites, depending on the metal of interest. Importantly, nickel and lead both seemed to have increased to the greatest degree, with some of the other metals' concentrations in the oyster tissue increasing by a less dramatic amount (Johnson et al., 2009). Used with permission.

Of the metals that were found to have increased in the oyster tissue, there is a plausible explanation for the increased amount of lead. Because of the rising floodwaters due to the storm, many homes and buildings were destroyed. Before the harmful effects of lead paint were known, it was more common for buildings to be painted using lead-containing products. It is possible that, due to the damage done to structures and buildings, extra lead was dissolved into the floodwaters, which eventually led to increased levels of lead in the oyster tissue. A similar explanation could explain the rise in other metal contaminants in the oyster tissue; because of the downed structures, as well as newly-churned layers of sediment, more metals may have been exposed to the floodwaters, leading to increased levels of colloidal or dissolved metals in the waters and, thus, more metal absorbed into the tested oyster tissue.

Another impact that is worth consideration is the phytoplankton bloom observed in the Gulf of Mexico for about four days after Hurricane Katrina made landfall. As hurricanes become more powerful over water, it is common for them to mix and churn the water, stirring up the sediment and nutrients contained in the ocean floor. Because Hurricane Katrina was a strong Category 3 storm, the winds were sufficient to stir up the dirt on the ocean floor. As the sediment was stirred up, enhanced nutrient supply was elevated to the surface by the wind-driven upwelling and vertical mixing present in the gulf waters (Shi & Wang, 2007).

Aside from the likely death of ocean life due to the churning and mixing of the Gulf waters, it is possible that there was excessive death of ocean life after the phytoplankton bloom due to the decomposing phytoplankton depleting the dissolved oxygen supply in the water. The process of oxygen depletion occurs via many oxidation reactions of the excessive organic material, most of which require oxygen molecules to drive the reactions to completion and decompose the organic materials in the water. Some orders of marine life cannot survive low dissolved oxygen levels and may suffer a major die-off after events such as phytoplankton blooms.

Economic Impacts

Hurricane Katrina was one of the most economically damaging natural disaster events in United States history, with an estimated 81.2 billion dollars in damage (Landry et al., 2007). Two of the major areas in which the hurricane exerted the most drastic impact included the energy sector and the ports/infrastructure, both of which experienced short and long-term damages.

Considering the energy sector, over 115 oil platforms were entirely lost throughout the 2005 hurricane season, with another 52 having sustained extreme damage. Considering this damage, it is estimated that 547 million barrels of oil were lost or unable to be produced due to the oil platform damage; at the price of oil from 2007 (70 dollars), this totals to a 38-billion-dollar loss (Petterson et al., 2006). To add to these numbers, an estimated 2,100 oil platforms in total and 15,000 miles of ocean floor pipeline were directly affected by hurricane-force winds from Katrina and Rita. What makes this damage so intense is the fact that these structures are responsible for about 30% of the total United States oil production and over 20% of the total natural gas production (Petterson et al., 2006).

Within the shallower waters of the Gulf Coast as Katrina neared landfall, the wind and waves disrupted network lines submerged below the sand that are used to carry oil and gas from the oil platforms in the gulf to onshore refineries. Because of the wind and wave forces inflicted by both Katrina and Rita in succession, a total of 247 subsurface pipelines were disrupted, leading to 418 minor pollution incidents within the outer continental shelf region off the coastline (Petterson et al., 2006). Aside from the offshore oil platform damages, Katrina in particular led to massive amounts of damage to refinery plants in Louisiana, Mississippi, and Texas, which together produce more than half of the entire United States supply of gasoline. Overall, the idling of oil platforms in the Gulf, the disruption of the submerged pipeline system, and the shutdown of oil refineries in three states ultimately led to the largest spike in oil and gas prices since 1973 (Petterson et al., 2006).

Along with the energy sector, the port of New Orleans and the infrastructure of the region both suffered large damages because of Hurricane Katrina. As a result of the wind and flooding, twelve wharfs were damaged, several hundred transportation barges were either grounded or sunk, and hundreds of miles of railways that serve New Orleans were completely destroyed (Petterson et al., 2006). As a result of the damages to the rail lines, trains were stopped for almost 400 miles on the CSX Corporation’s lines and around 200 miles on the Norfolk Southern

Corporation railways. These stoppages caused farm and industrial goods from the Midwest to suffer a short-term loss of access to foreign markets, as well as disruptions to the United States supply of basic food products and manufactured imports (Petterson et al., 2006).

Concluding Remarks – New Orleans, 2005

Hurricane Katrina is a weather event that demonstrates how some drastic impacts can be readily visible. However, it also shows how some of the acute effects, such as biological or environmental impacts, may be accidentally overlooked or forgotten. The goal of this past section was to shed light on the less obvious impacts and reveal the less acute ways in which Hurricane Katrina is classified as an extreme weather event.

Mt. St. Helens – Washington, 1980

Mt. St. Helens, located in the southern portion of the state of Washington, erupted violently in 1980 after over 100 years of dormancy. Although there were some signs of danger prior to the explosive eruption, there were unpreventable follow-up effects on the people of Washington and the surrounding Pacific Northwest states. In fact, the explosive nature of the eruption blew off a large chunk of the volcano itself, leaving behind a scar as evidence of the raw power of the event.

It is clear that the actual blast of the volcano is not a weather event by itself. However, the atmospheric ramifications of a large increase of particulate matter caused by volcanic ash, as well as the human impacts of the event, certainly classify a volcanic eruption into the category of extreme weather. The impacts of the eruption will be explored in the following sections and will provide insight into just how detrimental volcanic eruptions can be to human populations, even if the event is not typically classified as extreme weather by the general population.

Population Movement

Because the region around Mt. St. Helens is not extremely populated, there is a lack of data concerning the movement of people before and after the 1980 eruption. However, some interesting trends presented themselves shortly before the eruption took place. For a period of about six weeks from when the initial activity started until the actual eruption, the public interest in the volcano grew tremendously, due in part to the media's increased attention on the volcano (Perry & Greene, 1983).

As the level of danger grew with the volcano becoming more active, restricted zones were implemented in the regions surrounding the volcano. As the intensity of the volcano grew even more, local residents began to fear for their possessions and homes within these restricted zones and were allowed access for a few hours to collect belongings and check their properties (Perry & Greene, 1983). The next day, the volcano erupted violently, destroying some homes in the immediate vicinity. Therefore, although there was no apparent evidence of mass migration, there appeared to be a clear consensus that collecting belongings and moving out of the restricted zones close to the volcano was the right health and safety decision for these families to make.

Death/Injury

Immediately upon the explosion of Mt. St. Helens, there were people caught in the line of fire of debris from the portion of the volcano that blew off, as well as larger pieces of falling volcanic rock. In total, there were an estimated thirty-five known deaths caused by both landslides and the lateral blast (Baxter et al., 1981). Interestingly, of the 35 deaths, only 23 made it to autopsy; the findings showed that about 78% of the deaths were caused by asphyxiation from inhalation of volcanic ash, while other causes of death were not listed (Baxter et al., 1981).

Pyroclasts emitted from volcanos that are less than two millimeters in diameter are known as volcanic ash (Horwell & Baxter, 2006). Because of their small size, volcanic ash particles can easily be inhaled and, without appropriate care being taken, can cause severe respiratory damage. Since volcanic ash particles are not weathered, they are not oxidized and can therefore carry condensed volatile compounds such as acids, polycyclic hydrocarbons, and trace metals more effectively (Horwell & Baxter, 2006). Another danger associated with volcanic ash is that over 90% of the particulates are PM_{10}, which has serious implications in respiratory health by potentially leading to tracheitis and acute bronchitis (Horwell & Baxter, 2006). Interestingly, as seen in Figure 7 below, the number of acute bronchitis cases after the eruption increased dramatically from May 18 to May 20. It is plausible that the volcanic ash released from Mt. St. Helens contained a high concentration of PM_{10}, which then triggered acute bronchitis as a result of inhalation of large quantities of these particulates.

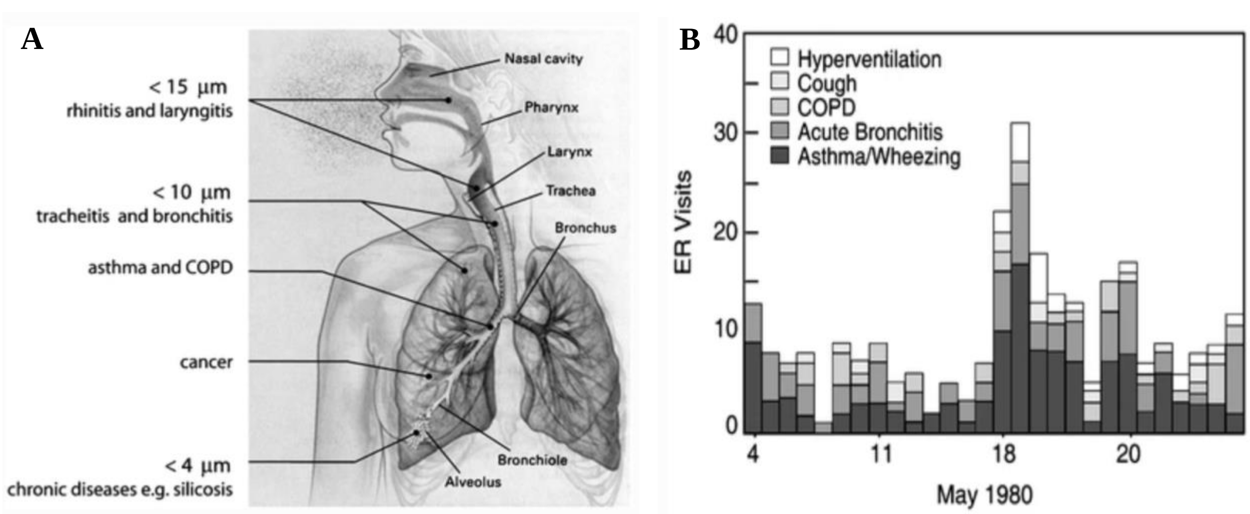

Figure 7. Different Sizes of Particulate Matter and Their Impacts on Human Physiology. Image A on the left depicts the various pathologies that can arise from different sizes of particulate matter found in the atmosphere. Image B on the right is a graph that depicts the sharp increase in emergency room visits both before and after the eruption (May 18), particularly for respiratory emergencies. After about two days, the graph shows that hospitalizations decreased and appeared to return to pre-eruption numbers after May 20 (Horwell & Baxter, 2006). Used with permission.

With the increase in emergency room visits during this event comes an interesting exception: the increase in hospital visits was mainly from people who had pre-existing respiratory conditions (Horwell & Baxter, 2006). In order to evaluate this, researchers conducted epidemiological studies with two groups: a group with pre-existing respiratory conditions and a control group without pre-existing conditions. The findings showed that one third of the patients who had pre-existing conditions experienced worsened symptoms after exposure to volcanic ash compared to a far lower proportion within the control group (Horwell & Baxter, 2006). The results not only indicate that chronic respiratory diseases are an important risk factor when evaluating the chances of developing adverse side effects from volcanic ash inhalation, but also that those with pre-existing chronic respiratory illnesses should take extra precautions in the event of exposure to fine particulate matter.

Based on the data from the severe haze in China in 2013, in that event the hourly indexes of $PM_{2.5}$ increased well above the upper limit of the Air Quality Index (Qiongzhen et al., 2015). Because of the concentration and size of the $PM_{2.5}$ observed during the event, one could assume that the particulate matter penetrated far into the respiratory systems of the people exposed to the pollution. As a result, based on this known exposure, as well as the information in Figure 7, it is presumable that an increase in the number of chronic respiratory diseases may have been observed, although there is not any hard evidence of this concept. A follow-up study should be conducted to determine if there was indeed an increase in respiratory diseases, such as silicosis, because of the severe haze event in China.

Atmospheric Chemistry

As Mt. St. Helens erupted, thousands of tons of ash were hurled into the atmosphere, much of which ultimately came back down to the surface of the earth. However, a significant amount of the ash remained in the atmosphere and changed the chemistry occurring at various elevations. After the Mt. St. Helens eruption, scientists evaluated the content of its ash to better understand the alterations to atmospheric chemistry caused by that eruption.

Measurements of the peripheral plume emitted by the volcano showed that the concentrations of particles less than two micrometers and greater than two micrometers in diameter were 1,500 and 20,000 times greater than found in ambient air, respectively (Hobbs et al., 1982). In fact, the total atmospheric contribution of Mt. St. Helens from March 28, 1980 – March 28, 1981 totaled roughly two teragrams, or about two million metric tons. Similarly, fluxes of condensation nuclei in the atmosphere as a result of the plume increased from $1x10^{16}$ to $2x10^{17}$ per second (Hobbs et al., 1982).

Within the plume effluents, many different gases were found, including H_2O, SO_2, H_2S, CO_2, N_2, NO, CO, CH_4, Cl_2, COS, and CS_2. A large amount (between 35 and ~100%) of the sulfur found in the plume was in the form of H_2S during the paroxysmal and intraeruptive periods of the event (Hobbs et al., 1982). Unfortunately, H_2S is known to cause nervous system damage and lead to seizures, coma, and death. Although a large number of different gases were observed entering the atmosphere, most of them remained in the troposphere, which is the layer of the atmosphere closest to Earth’s surface. However, roughly 1% of the tropopause (the dividing line between the troposphere and the stratosphere) plume was estimated to have reached the stratosphere (Hobbs et al., 1982).

Because of the high volume of volcanic ash in the immediate days following the eruption, surface temperatures dropped by 8°C compared to the seasonal average due to the absorption of solar radiation by the ash itself (Langmann, 2013). Importantly, the color of the ash plays a crucial role in the way the climate will be affected. Dark-colored ash is typically low in silicon and high in iron, while light-colored ash tends to be high in silicon and low in iron. In the light-colored ash found in the Mt. St. Helens eruption, the tendency was to reflect two to three times more incoming solar radiation than the darker-colored ash, which explains the drop in surface temperature experienced after the eruption (Langmann, 2013). Depending on the time of year, a temperature drop could mean the difference between experiencing and not experiencing a freeze, which could have serious implications for the crops growing in a given region. For many plants, a freeze means certain death, which would lead to a major food shortage in the affected areas.

One final subject worth exploring is the sulfate chemistry that occurs in the stratosphere following a volcanic eruption. It has been reported in the scientific community that sulfate aerosols scatter incoming solar radiation, thereby lowering the temperature on the earth’s surface below (Zhu et al., 2020). Further, it is known that the absorption of some solar and infrared radiation by these sulfates works to increase the temperature in the stratosphere (Zhu et al., 2020). Another impact of these sulfate aerosols in the atmosphere is that they function as surfaces for halides to adhere and become activated, thereby enhancing ozone depletion (Zhu et al., 2020). Interestingly, one of the effects of the Mt. St. Helens plume cloud was the depletion of the ozone layer in the atmosphere (Hobbs et al., 1982), which can lead to an increase in exposure to harmful UV rays from the sun.

Economic Impacts

Because the region surrounding Mt. St. Helens is not very populated (<8,000 people), there were likely not many structures in the immediate vicinity that were destroyed by the initial blast of the volcano. However, as mentioned previously, as Mt. St. Helens’ activity levels increased after over 100 years of dormancy, the media drew much attention to the volcano, leading to the “booming” volcano industry that grew in the area (Perry & Greene, 1983).

However, as the danger of the volcano increased, the county issued restrictive zones close to the rim of the volcano, leading to a decline in this business. Because of the decline, it is certain that Skamania County, the county where Mt. St. Helens is located, suffered short term revenue losses. Also, with the destruction of some homes in the immediate area, it can also be assumed that homeowners were devastated by the destruction of their homes and suffered substantial financial losses. However, due to a lack of information necessary to draw specific and factual conclusions, the offered explanation concerning potential economic losses is only speculative.

Concluding Remarks – Washington, 1980

Most observers would likely agree about the extremity of the Mt. St. Helens eruption. However, aside from the immediate mortalities caused by the eruption, as well as the visible ash that returned to the earth’s surface, many of the implications of such an eruption may have gone unnoticed by most people. The goal of the exploration of this eruption was to shed light on the various ways extreme weather can impact different aspects of life, whether it be acute health impacts or any chain of effects arising from the dropping of the daytime temperature.

Final Conclusion

A cursory analysis of the above three extreme weather events reveals that some prominent impacts of an extreme weather event are readily visible, while less obvious consequences may be more easily missed. These events can have many implications on population movement, health, biology, chemistry, the economy, and many other areas of life that are worth exploring to truly understand the full effect of these extreme weather events. Hopefully, after more research, a full understanding of the way extreme weather impacts humanity will be reached and some of the negative consequences of these events can be minimized to further protect humanity and the world in which humanity resides.

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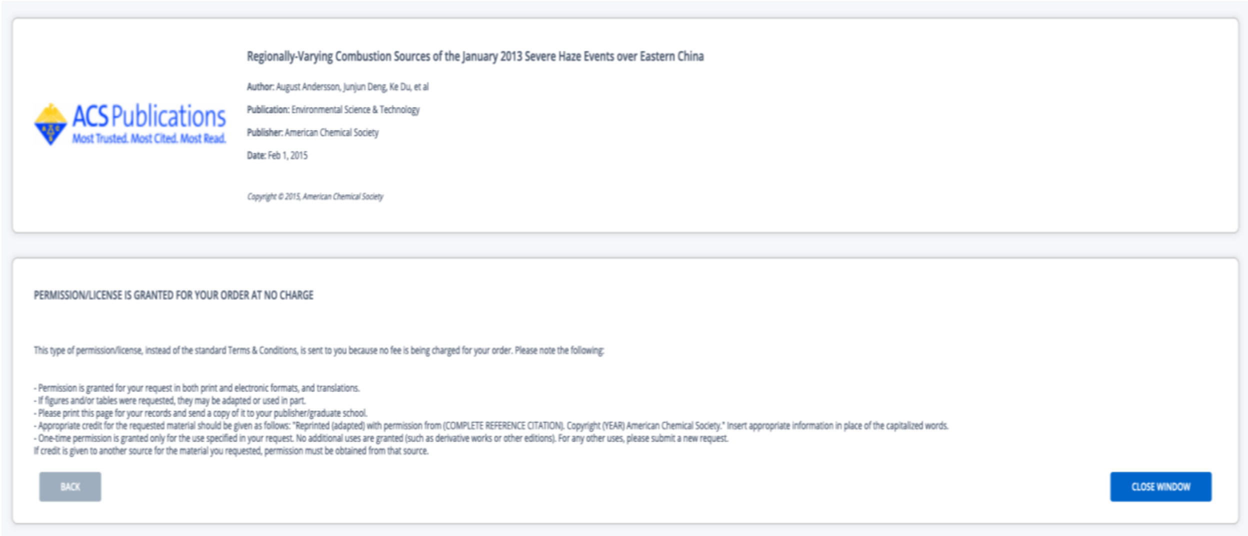

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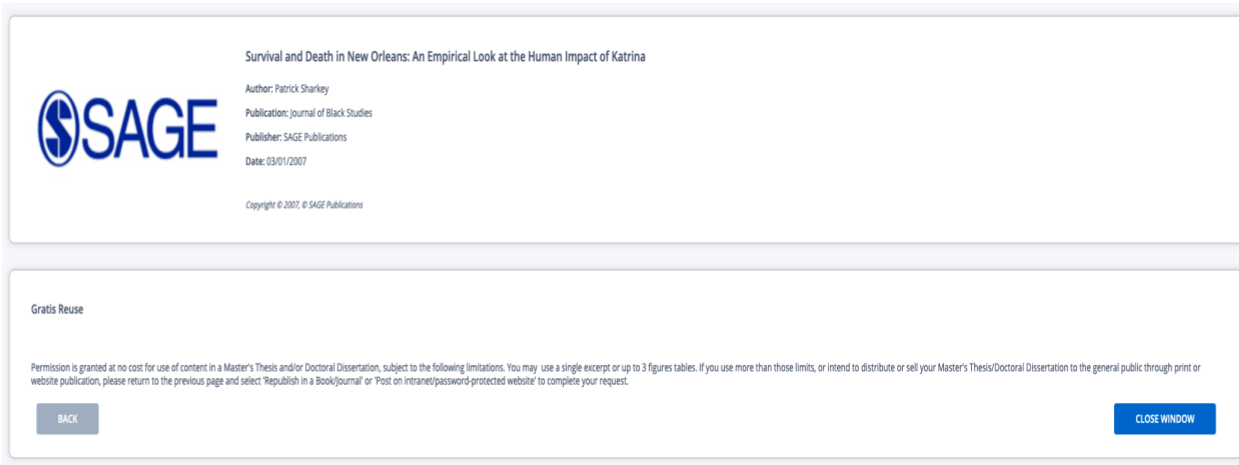

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