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# The Impacts of Climate Change on the Field of Emergency Management

Brian C. Newcomer

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# The Impacts of Climate Change on the Field of Emergency Management

A Master Thesis

Submitted to the Faculty

of

American Military University

by

Brian Carl Newcomer

In Partial Fulfillment of the

Requirements for the Degree

of

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ABSTRACT OF THE THESIS

THE IMPACTS OF CLIMATE CHANGE ON THE FIELD OF EMERGENCY MANAGEMENT

by

Brian Carl Newcomer

American Public University System, June 16, 2016

Charles Town, West Virginia

Professor: Dr. Robert Ditch, Thesis Professor

While the argument continues regarding the reasons behind climate change, the fact remains that the climate is indeed changing. These changes are projected to impact the frequency and intensity of storms in the future. This case study investigates current and predicted changes in the intensity of hurricanes, flooding, tornadoes, drought, and wildfires and how those changes affect the profession of emergency management. Specifically, current decision making regarding planning, mitigation, and adaptation is based on a historical perspective though many of those decisions have impact 50 – 100 years into the future. As natural disasters including hurricanes, tornadoes, drought, floods and wild fires increase in intensity and frequency due to anthropogenic climate change, they will exceed current protection methodologies in mitigation and adaptation thereby increasing vulnerability for people and property to future hurricanes, tornadoes, drought, floods, and wild fires. The tools and methods must be updated to incorporate future change as well as historic trends while policy makers and emergency management professionals need to incorporate potential changes in their decision making regarding planning, mitigation and adaptation. Failure to incorporate these changes may lead to more deaths and higher costs associated with more intense and more frequent storms in the future.

*Keywords: Emergency Management, Climate Change, Mitigation, Adaptation, Hurricane, Flood, Tornado, Drought, Wild Fire*

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# Introduction

## The Climate and Emergency Management

While the argument continues regarding the reasons behind climate change, the fact remains that the climate is indeed changing. Carbon dioxide concentrations in the atmosphere are 40% higher than pre-industrial revolution levels. Glaciers are disappearing at an alarming rate. Fresh water resources become harder to manage as icecaps disappear. The United States Global Change Research Program (USGCRP) (2014) states that while some of the changes wrought by climate change may be beneficial in the near term, most will be detrimental in the long term because the U.S. and its infrastructure were designed for the climate in existence at the time of their development. Thomella, Downing, Spanger-Siegfried, Han, and Rockström (2006) declared existing research communities have failed to reduce vulnerabilities in the face of climate change. Haines, Kovats, Campbell-Lendrum, and Corvalan (2006) believe human health is already adversely effected by climate change. The climate has changed and continues to change. The field of emergency management must adapt its practices and strategic planning practices to incorporate these changes.

According to the USGCRP (2014), the U.S. may expect a variety of long term changes due to climate change including another $2^{o}$F to $4^{o}$F increase in temperature over the next 30 to 50 years, sea level rise between 1 and 4 feet over the next 100 years, and increased quantity and strength of extreme weather events. A $2^{o}$F to $4^{o}$F temperature increase may result in reduced or elimination of mountain snowpack which many communities depend on for drinking water. Nearly 5 million Americans and hundreds of billions of dollars of property and infrastructure reside in the area threatened by a 4 foot sea level rise. Increasingly frequent and more dangerous extreme weather events may increase vulnerability to natural hazards for those that live and work in buildings and homes designed to withstand weaker storms. Infrastructure such as storm drain systems may fail to successfully divert the deluges associated with stronger downpours in the future.

In many areas, emergency management has not kept up with these changes in climate. For example, the National Flood Insurance Program (NFIP) established the 100 year flood standard in 1973. According to the US Geological Survey (2016), 100 year flood levels are constantly recalculated using historical and current data. In other words, computer modeling does not account for future changes. Flood insurance sold today to protect homeowners from significant flooding now may fail to provide adequate financial protection in the future. The Army Corps of Engineers continues to work on repairs to the New Orleans levee and dam system currently estimated to cost over $14 billion according to a New Orleans news director, Eve Troeh (2012). Some speculate whether the rebuilt levee system will withstand another hurricane like Katrina, much less a potentially larger hurricane in the future.

Flooding has substantial impact on the U.S. economy and the costs associated with flooding continue to skyrocket. According to the National Weather Service (NWS) (2016), flood costs in the U.S. topped $2.86 billion in 2014 and $9.10 billion in 2011 and the nation suffered 151 fatalities due to flooding over those two years. Unfortunately, much like the NFIP, the infrastructure designed to protect U.S. citizens and property and designed to last 50 years or more are based on historic flooding data. Mitigation measures fail to take into account the rising mean sea level or the increased severity and frequency of storms and flooding predicted by the USGCRP and the International Panel on Climate Change (IPCC). Additionally, coastal flooding is highly affected by the mean sea level which continues to rise. Though flood mapping may have decades between updates, they are historic in nature and fail to account for future sea level rise even as developers and engineers use current flood mapping data to create engineering marvels intended to last half a century or more. As time passes, these structures become more and more vulnerable to coastal flooding because designers failed to look forward in addition to the past.

A similar story continues with respect to tornadoes. According to the Centre for Research on the Epidemiology of Disasters (CRED) (2016), damages associated to tornadoes exceeded $27.Million in 2011 with an average annual damage total over the past decade in excess of $6.75 Million. Building code in the most tornado prone areas requires protection from wind gusts up to 115 mph leaving people and property vulnerable to tornadoes EF2 and greater, or nearly 50% of the tornadoes that have occurred in the past 50 years. The USGCRP (2014) predicts stronger and more frequent storms. These storms may lead to more frequent or more intense tornadoes for the U.S. as the climate continues to warm. If so, adherence to current code requirements may fail to protect people and property for the life of the structure.

According to International Code Council (2016), coastal wind protection requirements are higher at 135 mph – 180 mph which provides protection up to a category three to five hurricane. However, hurricanes are notorious for spawning tornadoes as they make land fall, and these protections, though better than protection requirements further to the interior of the U.S. still leave people and property vulnerable to tornadic activity. This research paper will focus on identifying potential areas of increased vulnerability due to climate change and possible investments in mitigation and adaptation for emergency managers in the field to incorporate into all phases of emergency management today.

## Research Purpose

As previously stated, adaptation and mitigation techniques in use today utilize historical data to develop protection mechanisms. The Corps of Engineers utilizes historical flood data to establish the Standard Project Flood (SPF) for a given study area in order to determine protection requirements when building dams and levees (Department of the Army, 1965). Hazard mitigation grants provided by the Federal Emergency Management Agency (FEMA) require construction to be compliant with pertinent building codes and area flood mapping (FEMA, 2013). Flood mapping is historical in nature unless recently completed in which case it may be considered contemporary as well. Flood mapping does not incorporate potential future floods of increased magnitude in their development which may leave homeowners, businesses and local governments vulnerable to storms of increased magnitude even as they comply with established building standards.

The International Building Code (IBC), the common building standard within the U.S. is updated every 3 years to incorporate changes within the construction industry in processes, materials, and hazards (International Code Council, 2016). The IBC is a vital piece of overall mitigation and safety against multiple hazards in building standards throughout the United States. The IBC targets establishes standards by risk level. Risk level I buildings are low risk buildings such as farm buildings and storage sheds. Risk levels III and IV buildings include large capacity buildings such as churches and event centers as well as public safety buildings like hospitals. The IBC targets commercial structures, though it may also be applied to residential structures. Because the IBC is designed to meet requirements defined by the National Standards Strategy and updates on a relatively short cycle, it is quite responsive to change. However, the IBC utilizes historical data to establish building guidelines. Further, the IBC can be interpreted by local officials during implementation further reducing protection from future increases in storm magnitude. Even so, the IBC may be the most up to date and easily influenced building standard that, when used, offers current protection from multiple hazards including hurricanes, tornadoes, flooding, and wild fires.

According to the International Code Council (2016), the IBC recommends minimum engineering standards for protection from wind, floods and fires. For example, the IBC recommends protection against ultimate wind speeds between 100 mph and 170 mph depending on the structure's location in the continental United States. The IBC establishes fire standards utilizing temperature and time ratings to grade protection. Fire protection within the IBC s not impacted by the frequency of occurrence and in fact appears to assume a fire hazard is present regardless of geographic location. However, the IBC distinguishes between buildings closer than 10 feet and those with greater separation. Those closer than 10 feet apart must have higher fire resistance to fires from both within and without. Those with more than 10 feet distance between buildings have a lower requirement for protection from external fire threats. The IBC does not address the proximity of other combustible material such as woodland. Fire ratings are based on time and temperature testing. Building materials must undergo American Society for Testing and Materials (ASTM) standard temperature testing to be rated by hour of protection given. This standard test takes materials from ambient temperature to nearly 2000 degrees over a specified period of time. The test runs until the material meets or fails within the required time standard.

Single and dual family residential building standards may be found in the American Wood Council's (AWC) (2014) Wood Frame Construction Manual (WFCM). Again, like the IBC, the WFCM is updated regularly with recent editions in 2012 and 2015. The WFCM utilizes the same wind speed chart as the IBC. Most of the U.S. falls into an area with expected 115 mph wind loads. The west coast has a slightly lower requirement at 110 mph while the east coast increases from 115 mph to a maximum of 180 mph required wind load protection. U.S. islands and territories require even higher protection in many cases. The American Wood Council's (2014) WFCM states that winds are not expected to exceed these ranges more than 7% in 50 years or once every 700 years. The AWC depends on IBC data to develop construction standards which again rely on historical data and do not consider future increases in intensity or frequency of hazards predicted by climate scientists.

While most scientists cannot agree on how much change the climate of the future will bring, the IPCC and USGCRP both publish a range of potential changes to the climate. None of the current major building or engineering standards include even the low end of expected changes in their building standards even though many buildings are expected and even planned to last well into the next 50 – 100 years. This historic perspective may increase vulnerability as climate changes bring more severe and more frequent storms.

**Research Question:** What is the impact of anthropogenic climate change on the magnitude and/ or frequency of hurricanes, droughts, tornadoes, floods, and wild fires?

**Supporting Questions:**

How can planners incorporate these changes into mitigation and adaptation measures designed to improve future resilience?

Would incorporation of these changes into mitigation and adaptation prove cost effective?

## Literature Review

There is a wealth of information available on climate change. Much of the current body of knowledge related to climate change focuses on explaining anthropogenic climate change or human induce climate change, the mechanisms of climate change, and forecasting potential impacts of climate change. There is little specific literature related to the impacts of climate change on the field of emergency management and if emergency managers may incorporate climate change information to better plan for, adapt to and mitigate against disasters in the future.

Organizations such as the Intergovernmental Panel on Climate Change (IPCC) and United States Global Change Research Program (USGCRP) focus on the reasons for climate change and refining estimates of the potential long term impacts of climate change. Climate change research depends on a wide variety of interacting variables. Many climate change scientists agree that while the climate is definitely changing and we can measure current changes, it is very difficult to predict future changes because of the difficulty in quantifying the complex interactions within the climate into the future. For example, the speed at which polar ice caps melt and release carbon dioxide stored within the ice impacts the climate. The oceans ability to absorb more carbon dioxide may retard those changes as people and machines around the world continue to produce more carbon dioxide. Additionally, forests that convert carbon dioxide to oxygen disappear to make space for the farms needed to support an ever growing world population. Changes in one system impact other systems which cause second and third order effects in yet other systems. Quantifying the specific impacts of climate change over future decades and centuries is indeed a difficult proposition. However, most climate scientists do support ranges of possibility as a place to start. The IPCC, USGCRP, and other climate change organizations therefore propose ranges of minimum and maximum change based on current knowledge and projections as a place to begin strategic planning with regards to potential climate change. Even the most conservative climate change estimates may have far reaching impacts on the field of disaster management.

Other research has focused on the impacts within specific areas of emergency management. For example, Haines, Kovats, Campbell-Lendrum, and Corvalan (2006) investigated the impacts of climate change on health related emergency management issues. They utilized case study research to support their findings with an extensive review of pertinent literature. While they failed to find conclusive evidence that climate change has already impacted global health, they argue that the European heat wave in 2003 and current increases in tick borne encephalitis are related to climate change. While the study failed to identify climate change as the cause for recent disasters, the research goes on to elaborate the potential health related effects related to climate change. During extreme heat events, mortality increases. Flooding increases vulnerability for a variety of reasons including the immediate physical vulnerability during rapid onset flooding, reduced access to potable water and increased exposure to diseases in the aftermath of flooding. Infectious disease transmission may increase for some pathogens as the climate warms. Finally, while the authors concede that climate change will likely reduce global vulnerability to cold weather health issues, the adverse effects of climate change on health will greatly outweigh the potential reduction in cold weather vulnerability.

Holland and Bruyère (2014) investigate the impacts of climate change on hurricane frequency and intensity. In order to identify the probability of increased intensity and frequency due to climate change, they developed the anthropogenic climate change index (ACCI) which compares frequency and intensity before and after accelerated global warming trends due to greenhouse gas emissions. Holland and Bruyère postulate that if the IPCC's claims that the frequency of intense hurricanes will increase and that the climate system has already warmed is true, then there would already be an observed increase in the frequency of more intense hurricanes. Their data shows that hurricane intensity has indeed increased even though hurricane frequency has not and that the increased intensity is very likely due to the global warming brought on by climate change. According to Holland and Bruyère (2014), "the increases are substantial, approaching a doubling in frequency of Cat 4 and 5 hurricanes" (p. 617). They further evaluated the frequency of all hurricanes and observed an approximately equal reduction in category 1 and 2 hurricane frequency. Utilizing the ACCI to compare hurricane intensity with temperature increase, the authors found that intensity increases by approximately 40 percent for every degree Celsius increase in temperature.

Flannigan, Stocks, and Wotten (2000) simulated the impact of climate change on wild fires utilizing two general circulation models as the best models to predict the impacts of climate change on a larger scale. According to the authors, temperature increases associated with climate change over time are important to the outcome, but so are other changes such as changes in precipitation and wind. Flannigan, Stocks and Wotten incorporated the forest Fire Weather Index (FWI) as an evaluation tool in their study which clearly forest fires are expected to increase in frequency due to climate change.

The USGCRP (2014) links current increases in flooding magnitude and frequency to climate change. Increases in flooding magnitude are associated with larger magnitude downpours due to changes in climate. Wilby and Keenan (2012) discuss the impacts of climate change on flooding and present recommendations for flood adaptation and mitigation incorporating the potential impacts of climate change. Wilby and Keenan (2012) state that flooding is the most common natural disaster globally. The author's argue that many factors influence flooding including future land usage and site specific factors such as ground permeability not just climate change. As such it is difficult to make broad projections regarding the impacts of climate change on future flooding events. Even coastal flooding which can be tied directly to a rise in sea level is also linked to local factors. While climate change may not be the only culprit and the degree to which human anthropogenic climate change may be responsible for more frequent and larger flood events may be argued, the authors point out that business as usual cannot continue when planning for, mitigating against and adapting to the floods of the future. Planners and engineers must incorporate a more strategic, forward looking view rather than just the current historical view as they determine proper mitigation and adaptation techniques, especially for long lasting infrastructure improvements.

The IPCC's (2014) fifth assessment report from working group one concluded that although previous assessments reported medium to high confidence that past droughts may have been linked to changes in climate, new arguments for and against the link between climate change and droughts leads to lower confidence that globally recent droughts are directly linked to climate change. In fact, droughts may have reduced in both duration and magnitude in Central North America and Australia. However, the assessment also concludes that regionally there is a higher likelihood that the climate caused larger droughts and longer lasting droughts specifically in the Mediterranean and West African regions. Scientists participating in the IPCC fifth assessment project that droughts will continue to increase in duration and magnitude regionally and predict climate change will influence drought more globally as the climate warms over time. Hoerling and Kumar (2003) argue that as the climate warms effecting sea surface temperatures around the globe in conjunction with normal El Niño – Southern Oscillations (ENSO), droughts will worsen in many regions around the world. While ENSO patterns have not changed greatly, surface sea temperature increases in the Indian and Pacific Oceans have increased greatly in response increases in greenhouse gases. Warmer ocean temperatures combined with reduced moisture conditions during ENSO will likely continue to worsen as ocean temperatures increase over time.

According to Grazulis (1990), while tornadoes occur elsewhere in the world, the U.S. experiences far more than any other nation. Elsner, Elsner and Jager (2014) analyzed tornadoes over the past 60 years finding evidence that changes in climate are effecting tornadoes. Though the number of tornado days in the U.S. is declining, the number spawning on each day of tornadic activity is increasing. Based on modeling, the authors hypothesize that the increase in multiple tornado producing days while the overall number of tornado days decreased is associated with changing climate conditions. Data available from the National Weather Service (2016b) shows that tornado frequency had increased from approximately 200 tornadoes in 1950 to over 1500 tornadoes in 2015. Experts recommend caution when utilizing this raw data without context. It is possible that better awareness and communication may have resulted in the more frequent identification of tornadoes though there may be little or no actual increase in tornado activity. Elsner, Elsner, and Jager believe the increase in multiple tornado days is a better indicator of the influence climate change is having on tornado activity.

**Summary of Findings**

Current literature supports the long term view that the climate is and will continue to change. These changes are dependent on a variety of complex interactions and variables and therefore difficult to accurately predict. Though there is a great deal of literature on the potential impacts of climate change, there is very little published regarding what emergency management practitioners today can do as they plan, mitigate, and adapt to disasters in the future incorporating these potential changes. Many researchers have already established climate change links to specific disaster types including hurricanes, drought, tornadoes, floods, and wild fires. While climate change impacts many types of disaster, it does not affect them in the same manner nor always equally increase or decrease risk across different types of disaster. The literature review supports the need for further research into how climate change impacts disaster mitigation and adaptation and how emergency management practitioners can incorporate this knowledge to reduce future vulnerabilities.

The following important points from the overall literature review are important as emergency management professionals plan for, adapt to, and mitigate against disasters:

1. Reputable international and national scientific organizations support anthropogenic climate change as a factor in increased warming trends around the world. These changes will likely bring disasters of increased intensity and frequency in the next 50 to 100 years.

2. Assuming reduced carbon emissions, the U.S will still experience at least 1 foot of mean sea level rise by the year 2100 and an additional temperature increase of $3^{o}$F.

3. Current mitigation measures are historic in perspective by utilizing past events to determine current protection requirements.

4. Not all changes are consistent across all regions of the United States. Where some may experience increased disaster frequency, other areas may experience reduced frequency. Increased drought in one area may be accompanied by more frequent deluges in another region of the United States

5. Global changes, such as those in the Indian Ocean or far Atlantic Ocean, may have implications in the United States. Emergency management professionals and policy makers

cannot afford to ignore the international community or changes half way around the globe as they prepare for climate change at home. The global climate is interconnected.

6. Business as usual will leave millions of people and vast amounts of property at increased risk. The world's climate is changing regardless of whether or not people accept the scientific reasons behind the changes. Disaster frequency and intensity have already begun to increase in some areas. Emergency management professionals and policy makers must adapt to these changes, incorporate potential changes brought on by future climate change into planning efforts and engineer mitigation measures to withstand what future natural hazards.

7. While there is robust literature available regarding the likely and potential impacts of climate change, there is very little research or proposed actions for those working in the field in the face of climate change. This lack of guidance in every field may result in poor resource investment and improper actions taken over the short and long term resulting in increased risk to people and property.

## Theoretical Framework/ Approach

There is a gap in the current body of knowledge regarding climate change and the field of emergency management. Specifically, current studies strive to show specific potential changes associated with climate change when applied to different disaster types. It fails to investigate necessary changes in current planning, adaptation, and mitigation models used by emergency management practitioners.  Emergency management practitioners are left to guess how they can best utilize existing and emerging climate change information to better utilize finite resources to plan for, adapt to, and mitigate against future disasters in a highly competitive economic environment. Research and guidance is needed to support these practitioners as they fight for the necessary resources to reduce vulnerability for the people and property they are charged to protect. This case study will identify areas to focus future research as well as areas for emergency practitioners to focus efforts now to reduce climate change induced vulnerability in the future.

**Theory:**

The case study will incorporate general systems theory which postulates that all systems are open to change when interacting with their environment. In systems theory, not only are disasters bound to be impacted by relevant climate change stimuli, but they are also susceptible to influence through planning, adaptation and mitigation measures. Systems theory is also appropriate to demonstrate how multiple disasters may be influenced by the same action as general systems theory has been used in the past to tie multiple disciplines together; this is called a trans-disciplinary theory by definition. General systems theory allows the researcher to evaluate systems versus all the sub-components individually: a daunting task when evaluating complex systems such as disasters and climate change.

However, general systems theory has its drawbacks. It is not ideal to develop specific answers for specific problem sets. It is a more generalized tool. For example, though discussing increased vulnerability from tornadoes or flooding, results will be general in nature and may not suit specific geographic areas or specific local environmental conditions. Emergency management practitioners will still need to apply deliberate consideration as to whether any recommendations fit their particular situation.

**Hypothesis**: Natural disasters including hurricanes, tornadoes, drought, floods and wild fires will increase in intensity and frequency due to climate changes and exceed current protection methodologies in mitigation and adaptation thereby increasing vulnerability for people and property to future hurricanes, tornadoes, drought, floods, and wild fires.

# Methodology

## Research Design

This research will incorporate both publicly available databases as well as peer reviewed literature to identify:

1. Changes, if any, in U.S. experienced hurricane, flood, tornado, wild fire, and drought frequency and intensity.
2. Whether or not research supports or fails to support linking current changes to anthropogenic climate change.
3. Research supporting or disputing future changes in frequency and intensity in hurricanes, floods, tornadoes, wild fires and drought due to anthropogenic climate change.

Intensity will be measured using applicable scales. Where scales are not utilized, associated costs will be used to measure intensity.

| Disaster Type | Measure of Intensity | Measure of Frequency |
|---|---|---|
| Hurricanes | Saffir-Simpson Hurricane Scale | Quantity of Hurricanes per 10 year period by Type |
| Flooding | National Weather Service Damage Costs | Quantity U.S. Flood Disaster Declaration per Year |
| Tornadoes | Enhanced Fujita Scale | Quantity of Tornadoes Reported Annually |
| Wild Fires | Suppression Costs | Quantity of Wild Fires Reported Annually |
| Drought | Drought Severity Index (D0 - D4) | Percent CONUS Land Mass Involved in Drought |

Table 1. Measures of Intensity and Frequency by Disaster Type. Sources include the National Hurricane Center (2016) regarding the Saffir-Simpson Scale; the National Weather Service (NWS) (2016a) for Flood Damage Related Costs; NWS (2016b) for Enhanced Fujita Scale Information; the National Interagency Fire Center (NIFC) (2016) for Wild Fire Suppression Costs; and the United States Drought Monitor (2016) for the Drought Severity Index.

Cost data will be adjusted to current U.S. dollar values to provide the ability to compare data from different time periods.

## Method

This research will employ a case study investigation of climate change evaluating qualitative and quantitative data to identify areas in which climate change impacts the field of emergency management using historical climate and weather data from the since 1965 as well as published literature on hurricanes, flooding, tornadoes, wild fires and droughts.

The study will evaluate and establish whether climate change is already impacting the severity and frequency of severe weather events. Next the study will incorporate qualitative findings from existing literature to compare the current and potential future effects of climate change on hurricanes, flooding, tornadoes, wild fires and droughts in order to identify areas that emergency management professionals can make changes today to better protect people and property tomorrow. The study will incorporate triangulation and investigate opposing views to increase reliability and validity.

## Data Collection

Data collection will focus on two areas. First, data collection will focus on historical government records to identify the quantity, strength and costs of hurricanes, floods, drought, tornadoes, and wild fires. Disaster intensity will be used in conjunction with hurricanes and tornados which have an intensity scale associated with them. Response and recovery costs will be used to illustrate the magnitude of those disasters that do not have a scale associated with their strength. Second, research will focus on existing literature to identify potential changes associated with each disaster type due to anthropogenic climate change. Literature will also serve as a tool to identify potential challenges to the field of emergency management due to climate change. According to the USGCRP, reliable climate models show that natural climate change and human induced climate change began to diverge in the late 60s (p. 5). Additionally, data sources become more reliable in contemporary times. Therefore, data collection will focus on U.S. disasters since 1966.

## Data Analysis

The study will evaluate historical records regarding the frequency, strength, and damages associated with hurricanes, floods, drought, tornadoes, and wild fires. Specifically, the study will utilize FEMA records on emergency declarations and damage assessments to develop a trend line illustrating disaster frequency and strength over the past century. Further, the research will utilize qualitative data regarding vulnerability from existing research to establish, if any, causal relationships between climate change and the listed natural hazards to identify potential areas of increased vulnerability due to climate change.

Next, the case study will extrapolate this data and apply it to future climate change to predict potential areas of increased future vulnerability associated with hurricanes, flooding, drought, tornadoes, and wild fires. According to Blanchard (2008), these natural hazards rank as the most expensive and most life threatening in the United States. USGCRP (2014) states the U.S. may see an increase in frequency and magnitude in these natural hazards due to climate change. The research will employ systems theory to help determine if changes in the climate have already occurred and any increased vulnerability.

## Bias

Potential bias surrounds the issue of anthropogenic climate change. While many scientists accept that current climate change is due to both natural and anthropogenic factors, some do not. Much of the skepticism is based on the difficulty to model anthropogenic climate change or define clear outcomes based on anthropogenic climate change. Climate change is a highly complex field with multiple second and third order effects for every input. In order to avoid bias on either side of the issue, the research will focus on minimum climate change factors and incorporate research from both those that support anthropogenic climate change as well as those that oppose that view point.

Frequency reporting may also be biased. Improved access to social media and technology devices may result in increased reporting. The research will focus on time periods since 1965 in order to reduce the impact of these variations. Additionally, as population increases and the U.S. population utilizes more and more land, they may experience these disasters more frequently, also contributing to increased reporting. For example, a tornado in an open field may have been observed but not reported 40 years ago. That same tornado moving through the same spot today may intersect with an apartment complex or industrial park as the U.S. population spreads out more and more. So, increased reporting may account for some increase in frequency. That is acceptable for this study as the same technology access and increased land use will likely continue into the future making them a constant influence from this point forward.

# Results

## Hurricanes

According to Holland and Bruyère (2014), hurricanes increased in overall intensity between 1975 and 2010 while globally, the overall frequency has not changed as global temperatures have increased over the study period. Their study included all cyclonic activity in the Pacific, Indian and Atlantic oceans. Category 1 and 2 hurricanes have dropped in frequency by approximately 20% while category 4 and 5 hurricanes have increased by approximately 20% over a .6 degree Celsius increase in global temperatures.

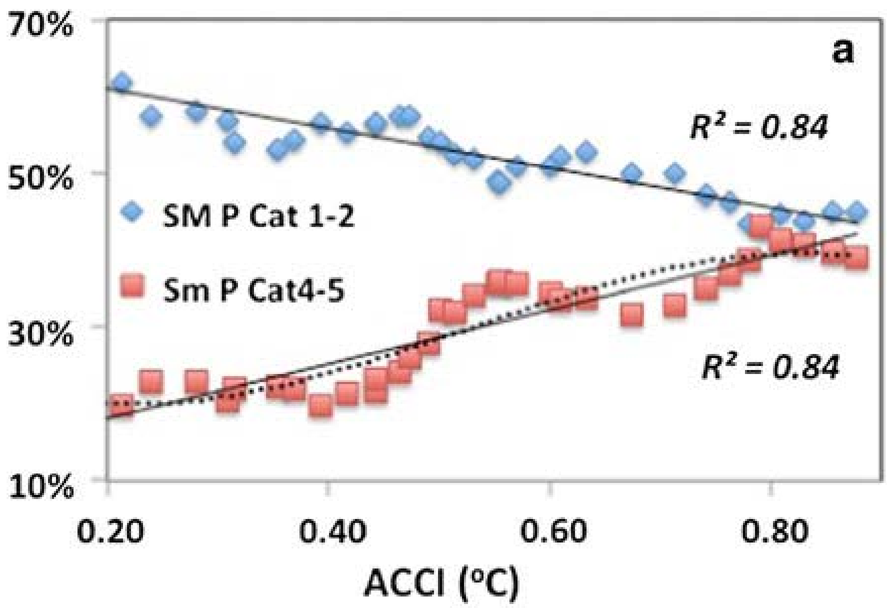



Figure 1. Hurricane Frequency Between 1975 and 2010 by Category as ACCI Increased. (Holland & Bruyère, 2014, p. 621).

Their study utilizes the Anthropogenic Climate Change Index (ACCI) which differentiates global temperature change based on human induced factors such as greenhouse gases and aerosols from natural climate change. Therefore the .6 degree Celsius change is not the actual temperature change but only the increase caused by human induced climate change.

Dunstone et al. also establish that hurricane frequency and intensity has increased since the 1970s (p. 846). Further, Dunstone et al. developed a model to project hurricane frequency over multiple years into the future. The model successfully matched historic numbers when historic data was input to the model. The model suggests that cooler tropical Pacific sea surface temperatures and warmer subpolar gyre both favor increased hurricane activity. They attribute these conditions to warming due to anthropogenic climate change.

The Weather Underground maintains a database of United States specific hurricane data. According to their information, the U.S. has not experienced corresponding changes in the frequency of category 1 and 2 or 4 and 5 hurricanes making U.S. landfall since 1966. Data from the Weather Underground shown in Figure 2 illustrates a spike in the frequency of category 1, 2 and 3 hurricanes between 1996 and 2005 but a subsequent drop off to near or below 1966 levels between 2006 and 2015 while category 4 and 5 hurricanes remain nearly constant over the 50 year period.

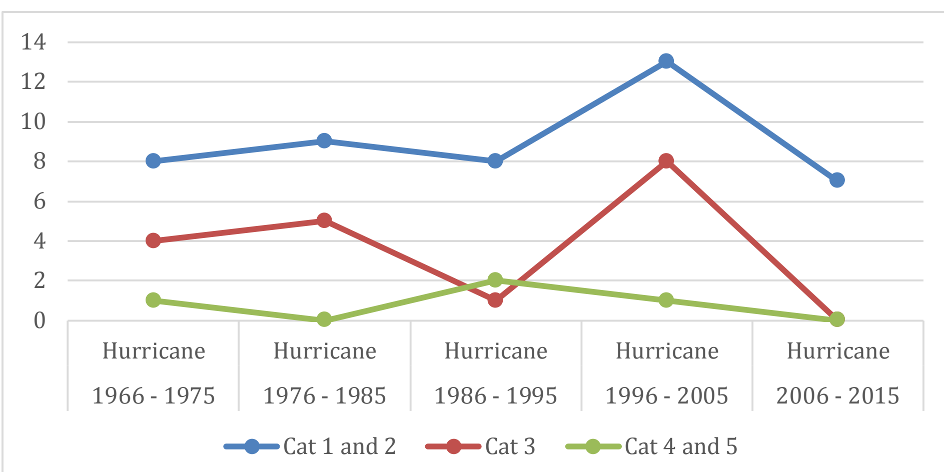



Figure 2. U.S. Hurricane Frequency between 1966 and 2015. Data compiled from the Weather Underground. (2016). *Hurricane and tropical cyclones: Hurricane archive*. Retrieved from https://www.wunderground.com/hurricane/hurrarchive.asp

According to the Weather Underground (2016), hurricane damage in the U.S. has dramatically increased during the same period. Damages from hurricanes have risen from $5.381 billion between 1966 and 1975 to $54.928 billion between 2006 and 2015 with a spike of $218.789 billion between 1996 and 2005. This increase is not due solely to increased intensity. According Thomella, Downing, Spanger-Siegfried, Han, and Rockström (2006) continued unplanned development of hurricane prone areas places more property and people at risk.

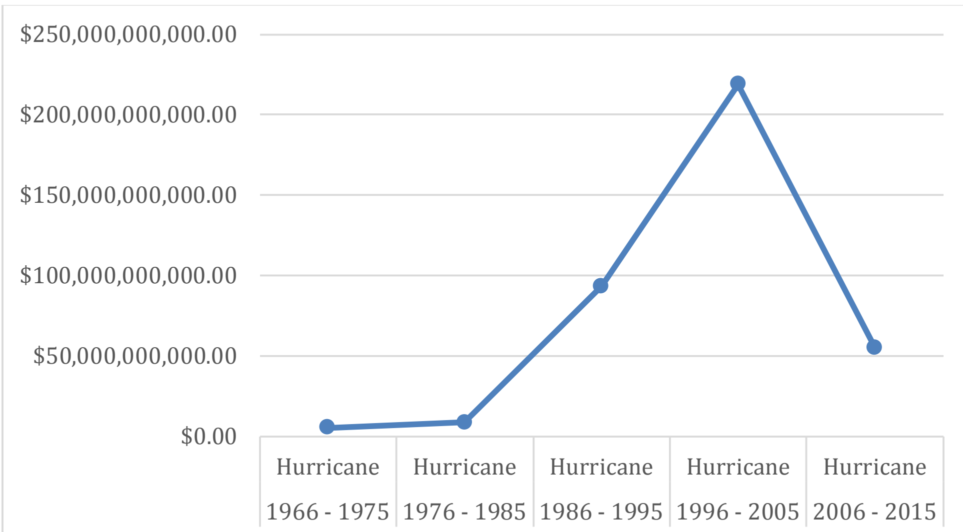



Figure 3. Costs Related to Hurricanes by Decade Since 1966. Data compiled from the Weather Underground. (2016). *Hurricane and tropical cyclones: Hurricane archive*. Retrieved from https://www.wunderground.com/hurricane/hurrarchive.asp

The ICC's (2012) current international building codes require engineering to prevent building structure failure in the face of 3 second wind burst between 115 mph and 180 mph for most occupied structures. Some states are implementing a higher standard, called the ultimate wind speed which is considered the maximum wind hazard for a given area. The map below graphically depicts the minimum requirement by location in the continental United States.

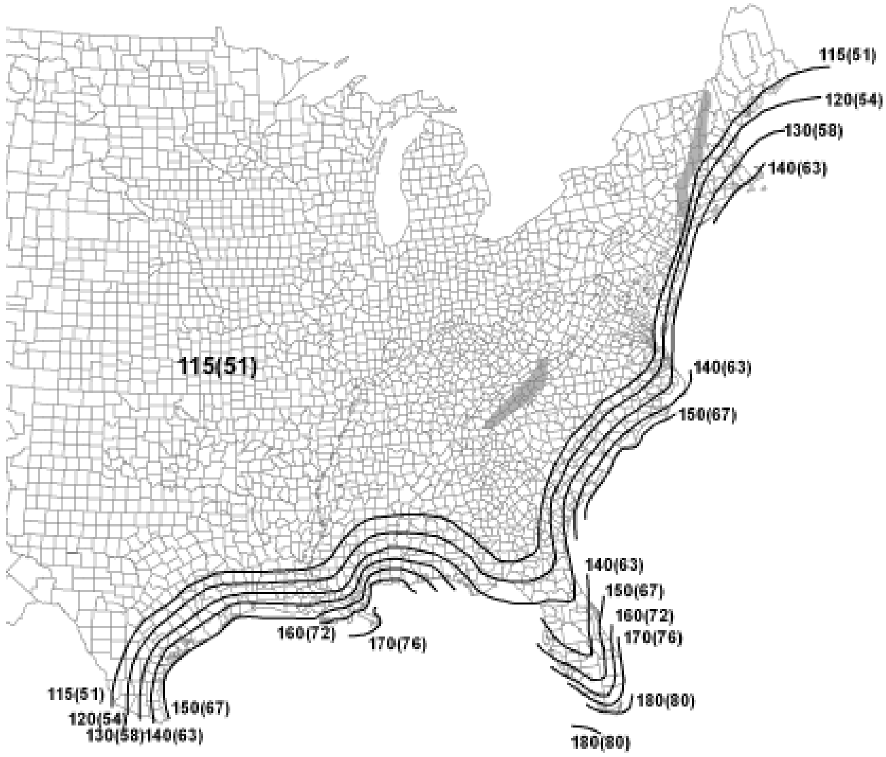



Figure 4. 2012 International Building Code Standards for Wind Load Requirements in the U.S. Illustration from the International Code Council. (2012). *International Building Code 2012 (2nd printing)*.Retrieved from http://publicecodes.cyberregs.com/icod/ibc/2012/icod_ibc_2012_16_sec009.htm

According to the National Hurricane Center (2016), the Saffir-Simpson scale defines hurricanes utilizing wind speed as the defining criteria. Tropical storms reach category 1 hurricane strength at 74 miles per hour (MPH), category 2 strength at 96 MPH, category 3 strength at 111 MPH, category 4 strength at 131 MPH, and category 5 strength above 155 MPH. Following current IBC standards would protect most of the Eastern coast line from Category 4 or higher hurricanes.

USGCRP (2014) states that hurricane intensity, frequency and duration of North Atlantic hurricanes have increased (p. 41). Additionally, category 4 and 5 hurricane frequency has increased. This statement concerns all North Atlantic hurricanes, not just those that have made U.S. landfall explaining the difference in data. Hurricane intensity and rainfall associated with hurricanes is projected to continue to increase as anthropogenic climate change continues.

**Tornadoes**

Elsner, Elsner, and Jager (2014) state that tornado frequency remained steady during the study period from 1975 to 2010, and hypothesize that tornado frequency will likely remain steady into the future. However, while the overall frequency has remained fairly constant, the number of tornado days has decreased resulting in more multiple tornado days and increased tornado concentration both spatially and temporally. Elsner, Elsner, and Jager propose that the changing climate is responsible for these changes in tornado concentration.

Data gathered from the TornadoHistoryProject.com (2016) suggests a difference in tornado frequency in the United States. According to the TornadoHistoryProject.com, the annual average tornado frequency has risen from 812 to 1226 since 1996.

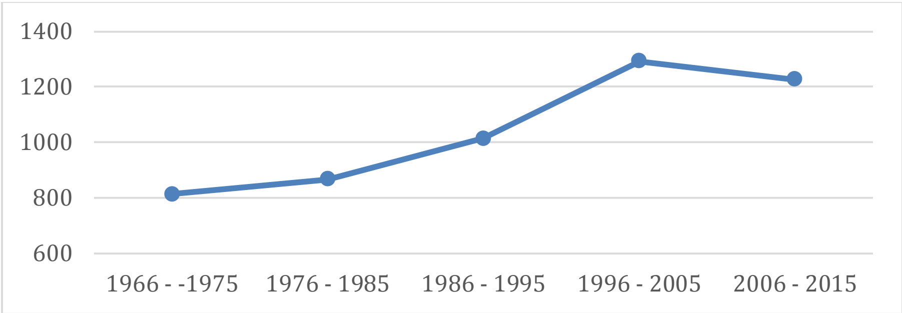



Figure 5. Average Annual Tornado Frequency in the U.S. since 1966. Source TornadoHistoryProject.com (2016).

The proportion of severe tornadoes decreased between 1966 and 2015. According to data from TornadoHistoryProject.com (2016), EF0 and EF1 strength tornadoes have increased in proportion from 66.48% of the overall number of tornadoes to 87.27% in the last decade. Most of the increase in EF0 and EF1 tornadoes comes from EF2 and EF3 tornadoes which reduced from 31.61% of the overall total of tornadoes to 11.93% of the overall amount.

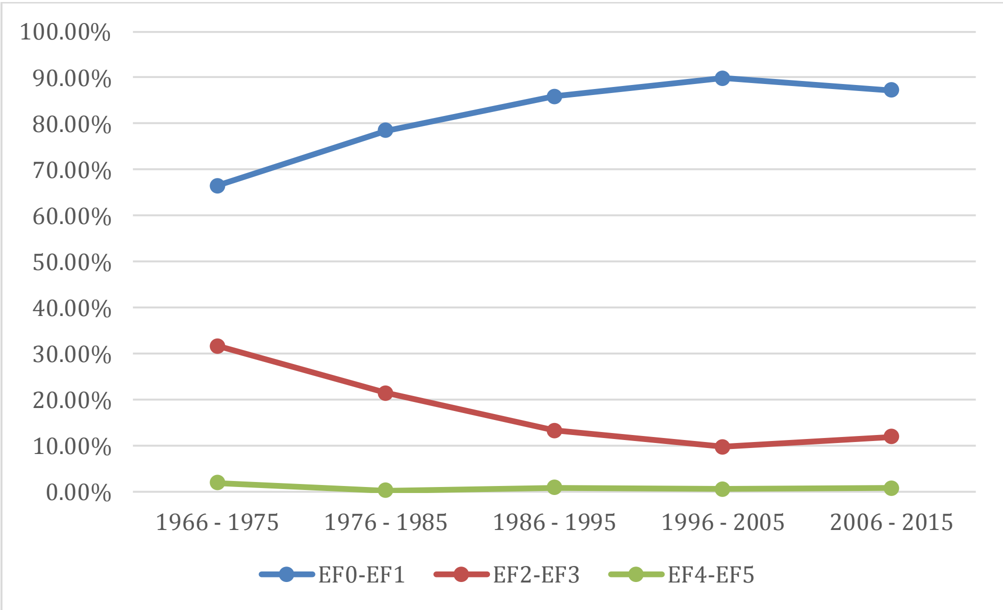



Figure 6. Tornado Frequency by Decade and Intensity. Data Source TornadoHistoryProject.com (2016).

USGCRP (2014) states that current data regarding tornadoes and other storms are not of sufficient quality to accurately determine any historical trends. The lack of quality data and the inability to model such small events accurately in climate models makes it difficult to determine the impacts of anthropogenic climate change on the future of tornadoes.

**Flood Results**

Floods frequency appears to have risen since 1966. According to the Centre for Research on the Epidemiology of Disasters (CRED) (2016), 200 floods were reported worldwide between

1966 and 1975 while 1667 floods were reported worldwide between 2006 and 2015. FEMA (2016) records show a clear rise in disaster declarations associated with flooding. Disaster declarations due to flooding have nearly doubled since 1966 going up from 14 in 1965 to 27 in 2015.

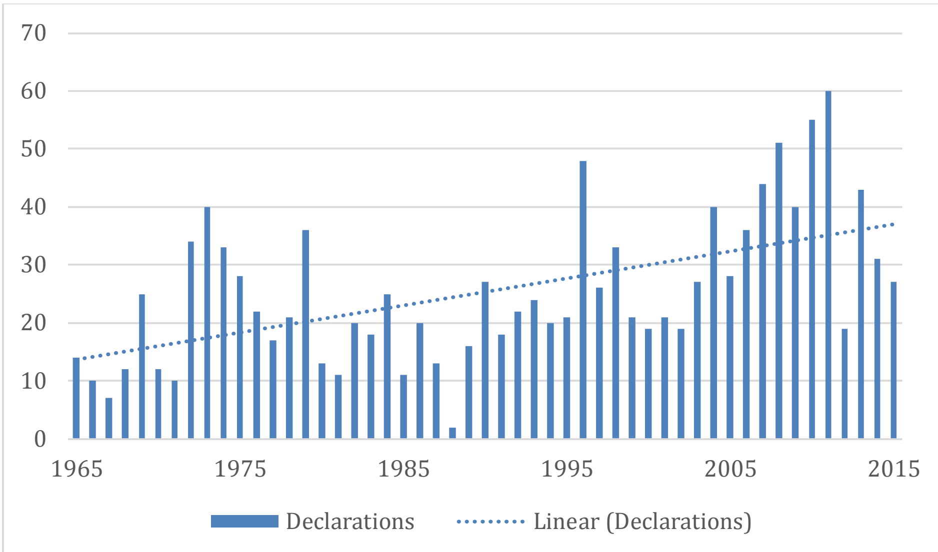



Figure 7. U.S. Disaster Declarations Due to Flooding 1965 – 2015. Source FEMA (2016).

Flood related damages in the U.S. follow the same trend. The National Weather Service reports flood damages between 1965 and 1974 totaling over $63 billion while reporting over $91 billion in flood damages for the ten year period beginning in 2005. Kundzewicz et al. (2014) and Hirabayashi et al. (2013) concur that flood relate costs have increased over time both regionally and globally. Wilby and Keenan (2012) conclude that flooding is the third most damaging globally after earthquakes and storms. Kundewicz et al. (2014), Hirabayashi et al (2013), and Wilby and Keenan (2012) suggest that the increases in flood related damages are tied to increases in population and structures within flood prone areas.

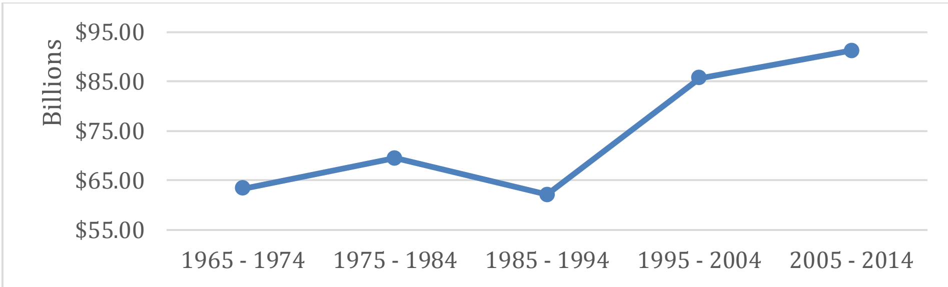



Figure 8. U.S. Flood Damage Totals by Decade from 1965 to 2014. Source National Weather Service (2016a).

Mitigation is an important protection measure to help reduce risk against many natural hazards but is especially common as a flood risk reduction measure. The Army Corps of Engineers plays a large part in designing and building public flood mitigation measures. The Army Corps of Engineers (1965) published the standard project flood determination standard in 1952 with revisions in 1965 which depends on historical data to model flood and water flow potential in a given area which are essential to the design of mitigation measures such as dams and levees. While the engineering process has become more automated, the basic fundamentals of the process remain dependent on historical data as they did in 1965.

USGCRP (2014) concluded that flooding frequency and magnitude in the Midwest and Northeast has already increased. Further, USCGGRP projects increases in frequency and intensity of extreme precipitation events which will lead to increased frequency and magnitude in flooding across the entire United States.

**Drought Results**

According to CRED (2016), global drought occurrence has increased from 54 droughts between 1966 and 1975 to 158 droughts between 2006 and 2015. Costs associated with droughts around the world have risen from $1.148 Million between 1966 and 1975 to $64.081 Million between 2006 and 2015. Carnicer et al. (2011) conclude that drought, due to climate change, is worsening in the Northern Hemisphere. The IPCC (2013) and USGCRP (2014) both conclude that both globally and within the U.S. drought severity will increase. According to the USGCRP (2014), drought severity or frequency may not increase across the U.S., but instead effects will likely be focused regionally in the Midwest and Southwest while the rest of the nation experiences increased frequency and intensity in heat waves. Drought conditions contribute to wild fire risk as well as creating issues with water availability, water quality, and increased agricultural challenges.

Data from the United States Drought Monitor (USDM) (2016) supports the USGCRP proposal that drought impacts will be regional in nature. According to the USDM database going back to January 2000, the percentage of the country in drought has actually declined slightly even as some areas of the country are experiencing more serious drought challenges.

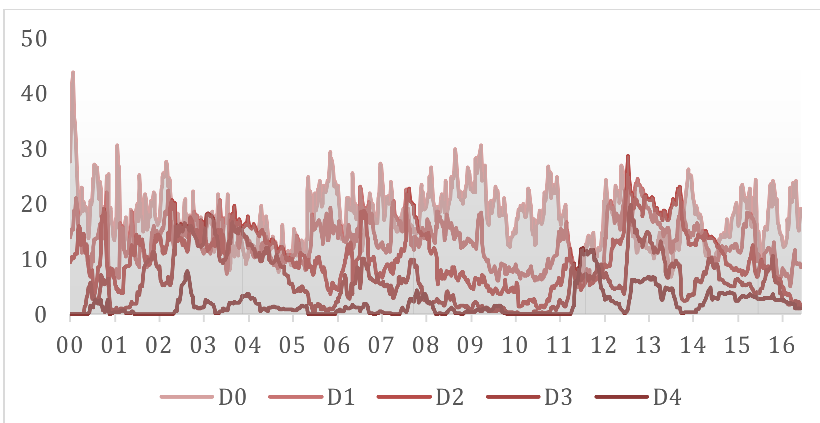



Figure 9. U.S Drought as Percentage of CONUS Land Mass Involved in Drought. D0 through D4 with D4 Identifying the Most Severe Drought Conditions. Source USDM (2016).

Hoerling and Kumar investigated droughts within the U.S., southern Europe and Southwest Asia linking them to near normal sea surface temperatures in the eastern Atlantic

Ocean in conjunction with warmer sea surface temperatures in areas of the Pacific and Indian Oceans. They attribute significant droughts in the U.S., Europe and southwest Asia between 1998 and 2002 to the combination of these warmer Pacific and Indian Ocean sea surface temperatures and normal Atlantic Ocean sea surface temperatures. They further attribute the warmer Pacific and Indian Ocean sea surface temperatures to green gas forcing and anthropogenic climate change.

USGCRP (2014) suggests that drought conditions over the last decade in the Western U.S. are the worst they've been in over 800 years according to tree ring data. Heat waves around the rest of the U.S. are more frequent and more intense since reliable record keeping in 1895. USGCRP projects drought intensity and frequency to continue its increase in the Southwest while heat waves intensify and increase in frequency around the rest of the United States (p. 38).

**Wild Fire Results**

The National Interagency Fire Center (2016) lists combined federal wild fire firefighting costs. Federal costs have risen from more than $500 Million in 1996 to more than $2 billion in 2015. Gorte (2013) states that the costs associated with wild fire protection and suppression have risen so much that they now account for nearly half of the Forest Service's annual budget.

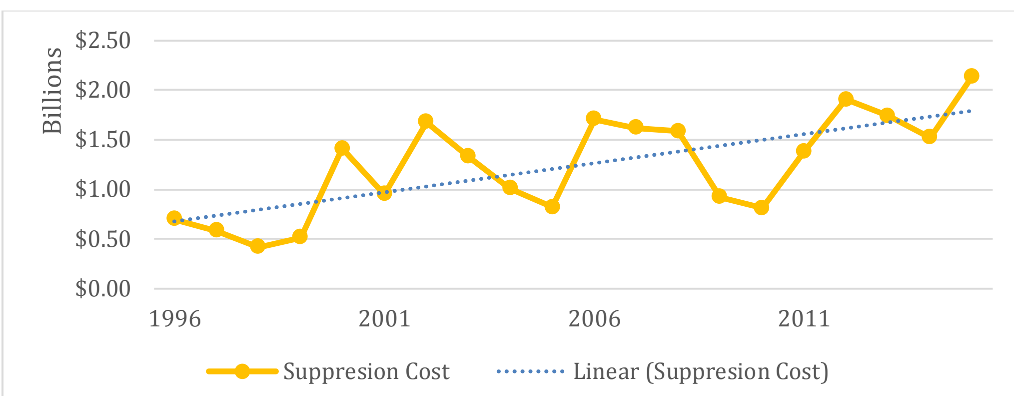



Figure 10. U.S. Forest Service and Department of Interior Fire Suppression Costs from 1996 to 2015. Source NIFC (2016).

Gorte (2013) attributes increased wild fire frequency and severity to three contributors. First, recent forest management practices have resulted in higher bio mass availability as fuel for wild fires. Second, climate change brings longer drier seasons which are more favorable for wild fires. And last, increased urban development in and against forested areas which he calls the Wildland Urban Interface (WUI), increasing risk to the people and buildings nestled now interfacing more closely with wooded environments. This WUI not only increases risk to the homes and people in the area, but also increases fire suppression resource requirements to save people and structures that would not be necessary in less urbanized environments. Gorte further points out that climate change may be contributing even more indirectly as pests and diseases that thrive in a warmer climate kill off trees providing even more ready fuel for wild fires.

Tackle, Braemer, Heilman, and Thompson (1994) conclude through global climate modeling that doubling the $CO_2$ in the atmosphere results in increased drying patterns and reduced moistening patterns in the United States. Increased drying results in increased dry fuel which increases the risk of wild fires. Flannigan, Stocks and Wotton (2000) further conclude that seasonal severity rates will increase by 10% - 50% over most of North America over the next century due to increased $CO_2$ in the atmosphere. The increased seasonal severity rate will result in more frequent and more severe wild fires as well as significant impact on ecosystems.

According to USGCRP (2014), wild fire frequency and intensity has already increased. USGCRP associates increased wild fire risk with increased drought conditions. As drought and heat waves dry regions, fuel becomes more easily ignited, fires move faster, and containment is much more difficult. USGCRP projects increased frequency and intensity in wild fires due to anthropogenic climate change through 2100 and beyond if carbon emissions are not substantially reduced in the near term.

# Discussion

## Global and Regional Differences

Overall, the data suggests that anthropogenic climate change has already affected extreme weather events around the world and in the United States. There are substantial regional differences in effects both as the U.S. region globally and further regions within the United States. While there may be a global increase in intensity and frequency in hurricanes, the U.S. has not experienced a coinciding increase in those hurricanes that have made landfall on U.S. coasts. There could be multiple reasons. As ocean temperatures change and atmospheric conditions change due to anthropogenic climate change, this may affect the course of hurricanes pushing them away from U.S. landfall. The lack of coincidence may simply be a result of measuring period and over time it will be seen that in the U.S. will experience more intense and more frequent hurricanes.

Regional differences within the U.S. coincide with ecosystem regions. Drier areas in the southwest are more vulnerable to warming and drying conditions and therefore exhibit more intense and frequent drought conditions while the rest of the U.S may only be experiencing intensifying more heat waves. Further differences impact regional difference such as topography, forestation, urban development, proximity to oceans, and more all influence regional response to climate change. For example, local urbanization or increased land usage for agriculture can affect how much heat is reflected or absorbed creating local and regional differences in warming trends. Each region reacts to climate change in its own unique way based on multiple, complex interactions within the region.

While each global or U.S. region may react differently to climate change over time, IPCC (2012) and USGCRP (2014) both agree that anthropogenic climate change will bring overall air and water temperatures, increased mean sea level, and increases in $CO_2$ concentrations in the atmosphere and in the oceans. Each region must identify the way these changes will specifically manifest in their particular region.

**Data Contradictions**

Data collection clearly illustrates multiple different perspectives and contradictions. The two tornado databases used paint different trends in historical data. Some differences may be due to reporting means. Where databases contradicted one another, literature was used to support the use of one database over another. However, it is clear that in many cases, more research and better record keeping is necessary to better inform the field of emergency management in specific areas.

**Hurricanes**

Global and U.S. historic data conflict. While Atlantic Hurricanes have increased in intensity globally as illustrated by Holland and Bruyère (2014), data from the Weather Underground (2016) suggests that hurricanes making U.S. landfall have not risen in either intensity or frequency. In fact, hurricanes making U.S. landfall dropped in overall frequency and intensity between 2006 and 2015 with the vast majority of hurricanes making U.S. landfall as category 1 and 2 hurricanes. Dunstone et al. suggests that hurricane frequency is increasing as surface sea temperatures in the subpolar gyre warm and tropical Pacific cool.

Though currently U.S. landfall hurricanes have not increased in either frequency or intensity, it is likely that this regional variation will tend towards the current global outcome matching increased frequency and intensity in hurricanes making U.S. landfall as anthropogenic climate change continues. It is unclear whether this regional variation is due to happenstance or if anthropogenic climate change is also changing the path of hurricanes. However, historically there have been large variations in hurricane frequency and while not impossible, it is doubtful that anthropogenic climate change is dramatically shifting the path of hurricanes away from the continental United States. It is more likely that recent reductions in hurricane strength and intensity are like previous periods of reduced hurricane intensity and frequency and that over time, the U.S. as a region will match the global trend in increased frequency and intensity.

**Tornadoes**

Of all the disasters investigated in this case study, tornadoes data and proposals are the most conflicting. Elsner, Elsner, and Jager (2014) suggest that while tornado frequency has remained constant, multiple tornado days have increased. Data from TornadoHistoryProject.com suggests an increase in tornado frequency but decrease in tornado intensity. USGCRP (2014) suggests that the quality of current data sources regarding tornadoes is too low to determine any trends in tornadic activity.

While USGCRP may be correct that data is insufficient to conduct good trend analysis, the data available is still worth review. Where large hurricanes have been recorded for decades in the media as well as by scientists, tornadoes have not enjoyed the same type of historical documentation. While flooding has been documented by government and private researchers alike, again tornadoes have not been recorded in the same manner. There has not been a public or private organization charged with documenting tornadoes. However, recent interest and research in tornadoes and the science surrounding them may well lead to better documentation in the future.

Much of the increase in frequency found in TornadoHistoryProject.com data may be attributed to increased public access to media, social media and technology. Additionally, it is possible that past tornadoes on open ground went undocumented because they did not incur any damage. As the U.S. population continues to increase, it is more likely that someone or something will intersect with tornadoes as they occur. As people and structures continue their spread, it is less likely that tornadoes touch down and move across open terrain without interacting with developed areas.

**Floods**

U.S. Disaster declarations due to flooding show a substantial increase in flood frequency over the past 50 years. There is an extremely high rates of concurrence that flooding has already worsened in both magnitude as measured by the costs associated with flooding. USGCRP (2014) proposes continued increases in both the frequency and magnitude of flooding. Multiple factors influence these potential increases.

Like every area experiencing accelerated changes due to anthropogenic climate change, flooding changes are a result of multiple influences. Increased urbanization and the increased use of non-porous materials increase the potential for flash flooding during intense deluges brought on more frequently by anthropogenic climate change. Increased land development within flood prone areas increases the potential for flooding disasters. As the mean sea level continues to rise, the effectiveness of natural coastal barriers to protect coastal land from the winds and surge associated with tropical storms and hurricanes is reduced. The continued rise of mean sea level places increased infrastructure, once well above sea level, at risk for flooding. The rise in sea level moves coast line in laterally as well, reducing the buffering potential lands provided through distance from water.

The rising sea levels increase risk in a variety of areas, but especially in coastal flooding. Even as land developers attempt to utilize current mapping in an effort to responsibly develop land areas near the coast, the buildings they design and areas they develop may be at increased risk of flooding 30 – 50 years from now as the mean sea level continues to rise.

The historic nature of flood mapping and mitigation engineering procedures is concerning. While the past offers insight, the future cannot be divined from past events. The Army Corps of Engineers designs and builds mitigation measures intended to last. If hurricanes increase in intensity and bring increased storm surge, those mitigation measures must incorporate the increased potential based on anthropogenic climate change to operate as intended for their intended lifespan. Failure to incorporate future changes may result in dramatic reductions mitigation capabilities over the life of the project or increased costs associated with adjusting to changes later in the projects life cycle. It is rarely cheaper to adjust something once it has already been built.

It is interesting to note that if anthropogenic climate change were not an issue, it is likely that current engineering standards and building codes would be sufficient for the life span of mitigation projects. It is only because anthropogenic climate change accelerates the process that engineers need to look farther forward in their design requirements.

**Drought and Heat Waves**

The data suggests increased frequency and intensity for drought in the Southwest United States. USDM (2016) data shows a decline in both frequency and intensity of droughts across the greater U.S. while California and the Southwestern are experiencing historic drought conditions. USGCRP (2014) suggests these regional trends will continue as anthropogenic climate change continues over the next century, adding the Midwest into the potential for increased drought severity and frequency.

According to Diffenbaugh, Swain, and Touma (2015), "California is the largest contributor to economic and agricultural activity of the United States" (p. 3931). They base their claim on having the largest cash farm receipts nationally. While their claim will likely be argued, the impact of Californian agriculture nationwide is large. Drought conditions effect not only their ability to supply agricultural products across the U.S., but also significantly impact the economy. California requires a complex water management and distribution system as most urban and agricultural lands are far from water sources. Diffenbaugh, Swain, and Touma believe that though urban and agricultural water use efficiency has increased substantially, resulting in a decline in per capita water use, future acute shortages may present greater challenges as much of the resilience in the system has been absorbed in prior water conservation efforts.

While the Southwest and Midwest may experience increased drought intensity and frequency, the rest of the U.S. will likely suffer increased frequency and intensity of heat waves. According to Anderson and Bell (2011), heat waves increase mortality 3.74% compared to non-heat wave days. If true, increased heat wave frequency alone will likely increase mortality rate. Increased intensity may impact the rate as well.

**Wild Fires**

As anthropogenic climate change accelerates warming increasing temperatures and reducing rainfalls in some areas, wild fires will likely increase in both intensity and frequency. These dryer conditions favor increased fire risk. Further aggravating the situation is the increased intersection of people and property in and against forested areas. These co-location strains fire suppression resources that must be diverted to protect people and property in areas they may have let burn otherwise. Not only are resources diverted, according to Gorte (2013), protecting people and property requires increased resources. This increased burden shifts fire suppression efforts to populated areas over non-populated areas and diverts financial resources from mitigation and adaptation efforts to suppression efforts.

While fire can be a forest's natural mechanism promote long term forest health, anthropogenic climate change is forcing more frequent fires which inhibit long term health. Flannigan, Stocks, and Wotton (2000) describe changes in forest ecosystems due to more frequent wild fires. Different tree types perform better under different burning cycles. For example, loblolly pine trees perform better under a 50 – 100 year surface/ crown fire cycle while ponderosa pines prefer a more frequent fire cycle. Changing the fire cycle may result in different species taking over under conditions more favorable to that particular species. Flannigan, Stocks, and Wotton speculate that southern tree species may migrate northward as the climate warms and that eventually, more frequent burning will increase the speed at which forests transition from forest area to grassland.

Wild fires effect climate change even as they are subject to the effects of climate change. As wild fires consume forests, they generate and release carbon into the atmosphere. Additionally, a healthy forests act as carbon sinks as trees pull carbon dioxide out of the air and convert it to oxygen and glucose through photosynthesis. Wild fires interrupt that cycle. The result is a burst of carbon into the environment and a reduction of carbon pulled out of the environment further contributing to the changing climate, albeit through what would be considered natural climate change and not anthropogenic climate change. This illustrates though how both may be linked and how anthropogenic climate change may also accelerate natural climate change.

**Purely Historic vs. Historic plus Future Best Case Decision Making**

Building and engineering standards currently in use favor a historical perspective for design and development of mitigation measures. FEMA enforces adherence to a standard that mandates engineering based on historic hazards in the given area in order to receive funding assistance. As already noted, the Army Corps of Engineers utilizes the standard project flood determination to design and build mitigation measures which is historic in nature. Hurricane prevention and tornado prevention rely on building standards firmly grounded in historic requirements and developments. Forest management practices in response to wild fires are grounded in historical precedence and study.

Incorporation of future changes in climate change is necessary in order to realize the full potential of investments in adaptation and mitigation. Otherwise, projects may fail in the face of the increased intensity or frequency projected for many natural hazards of the next 50 – 100 years. Many structures are built to last at least 50 years. According to the U.S Army Corps of Engineers (1997), the designed service life of flood control projects is 100 years. O'Connor (2004) suggests that the majority of residential homes last between 76 and 100 years and that architects, structural engineers, builders and developers expect commercial and public buildings to last between 50 and 87 years depending on their primary building composition (masonry, wood, concrete or steel). As buildings are expected to last this long by their designers and builders and since data show that buildings actually meet that expectation, it is necessary to incorporate potential changes to the environment that may occur through the expected life of the project during the design and construction phases of the project.

While a great deal of research is available on the potential effects of climate change across the U.S. and regionally, there is very little guidance to practitioners in the field on how to change their actions to improve long term results in the face of anthropogenic climate change.

**Continued Land Development**

A factor that underlies many of the disaster types studied deals with continued land development for human usage. Tobin and Montz (1997) identify a natural disaster as the intersection between the actual human use system and the actual extreme natural event.

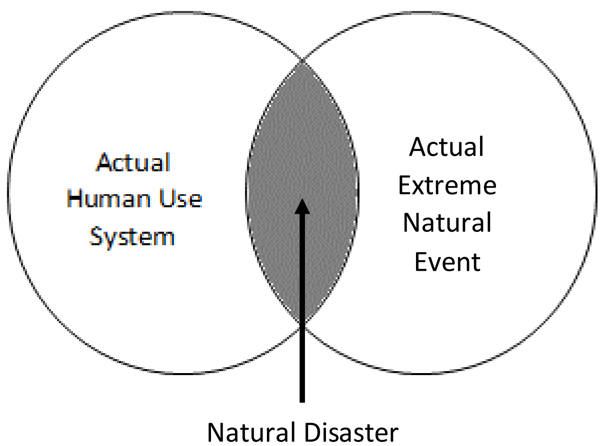



Figure 11. Tobin and Montz Natural Disaster Intersection. Source Tobin and Montz (1997).

According to Colby and Ortman (2015), the U.S. population will grow from 319 million to 417 million between 2014 and 2060. Increased population may require increased housing, infrastructure and agricultural land use to support the larger population. This increased land development will have multiple side effects. Even if disasters remained stable in magnitude and frequency, as the actual human use system grows, there may be more frequent interaction with extreme natural hazards resulting in natural disasters. Disasters may grow in magnitude as more people will be impacted by them.

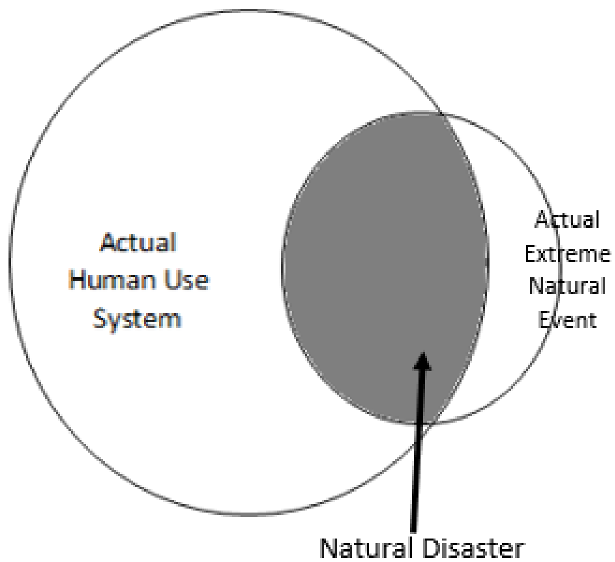
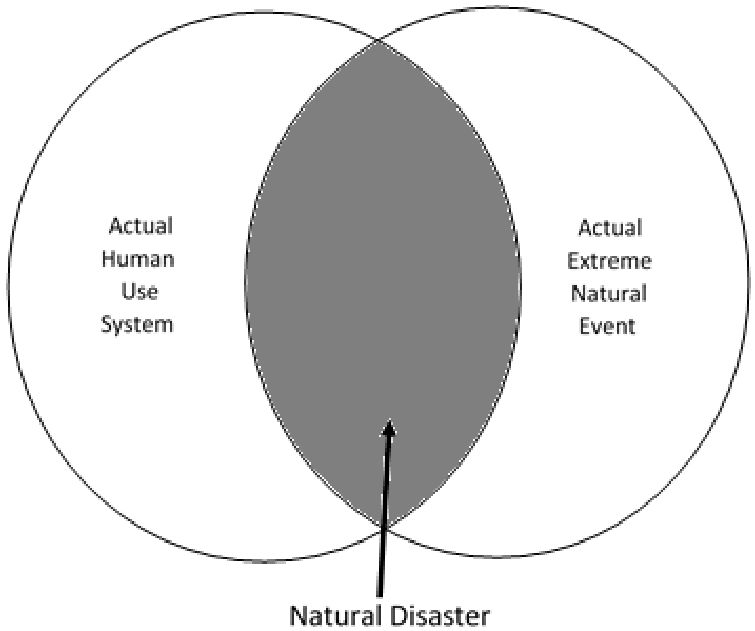



Figure 12. Potential Increase in Natural Disaster Occurrence Based on Population Increase. Adapted from Tobin and Montz (1997) Natural Disaster Model.

Additionally, as stated before, changes in the landscape change how areas respond and interact with the mechanics of anthropogenic climate change. As land is cleared and urbanized to support a larger population, it may result in more heat absorptive surfaces increasing experienced air temperatures regionally and locally worsening drought and heat waves. Urbanization also has second and third order effects on hurricanes and tornadoes as more people and property are exposed to them, on flooding as it changes the dynamics of water flow especially in flash flooding, and in wild fires as more people live in or against remaining forested areas.

As anthropogenic climate increases the intensity and frequency of some natural hazards while the population continues to increase, the intersection between the human use system and natural hazards increases even more. The U.S. should expect more disasters to occur under these conditions.




1. Figure 13. Potential Increase in Natural Disaster Occurrence Based on Population Increase and Climate Changes. Adapted from Tobin and Montz (1997) Natural Disaster Model.

**Political Will for Change**

The effects of climate change are complex and interwoven. Adopting policies to address climate change may be even more complex and interwoven. Perry and Lindell (2007) describe an emergency management policy making process that may be sequential and yet complex. Drabek (1987) describes apathy towards disaster planning as a social reality. Auf der Heide (1989) describes apathy as a lack of awareness, underestimation of risk, reliance on technology, and/ or fatalism. Emergency management professionals must understand, overcome and work around these principles as they develop, plan, and propose policy changes.

Tobin and Montz (1997) suggest policies may be formed through 3 avenues: regulatory, programmatic mandated, and programmatic cooperative. The regulatory approach includes zoning, permitting, design standards, subdivision, and building codes. The programmatic mandated approach includes land use plans and programs, hazard disclosure, warning and emergency management, and relief efforts. Programmatic cooperative options include fiscal inducement, insurance, public loss recovery, relocation, and direct public acquisition. Emergency management professionals will need to use the full breadth of these available tools to incorporate policy protections against the effects of anthropogenic climate change.

It is already difficult to push mitigation and adaptation when so many other contemporary emergencies in the political arena fight for interest and funding. Many of the effects of climate change, while already present are insidious and fail to reach the top of the public's agenda. Even as disaster strikes, the immediate rush is to take care of victims and rebuild, not to discuss how policy can be changed to incorporate climate changes of the future to better protect people and property.

# Conclusions and Recommendations

The climate is changing all around us. Most researchers agree that anthropogenic climate change is motivating much of the accelerated change. According to USGCRP (2014), even if we stopped all carbon emissions today, the climate would continue to change for the next 50 years or more based on the pent up energy already in the climate system. People and more specifically the field of emergency management must embrace the changes and move forward with planning, adaptation, and mitigation inclusive of anthropogenic climate change.

## Forward and Backward Perspectives

Past successful practices have proven the importance of including relevant historic data and information in planning, adaptation, and mitigation efforts. To ignore the past history of Red River flooding or best practices gleaned from frequent wild fires in the West would be irresponsible. Past experiences can help inform risk decisions and resource prioritization as well as provide perspective on existing natural hazards in a given area. However, the past is not the only information needed to best plan, adapt, and mitigate against existing hazards. Changes in land use, planned urban development, and yes, the effects of climate change must also be incorporated to build the best foundation for decision making.

While climate scientists cannot agree on the degree to which elements of the climate will change, they have developed a range of possible changes based on modeling. It is currently infeasible to accurately forecast changes at the national and regional level because scientists do not fully understand all the interactions and dependencies within the climate system. As such, emergency management professionals may choose to adopt changes in policy and action based on the minimum expected climate changes. For example, while oceans may rise up to 4 feet by the year 2100, they may also only rise one foot in that same period. Though the projection lacks specificity, the USGCRP (2014) report reflects high confidence that the global mean sea level will rise.

All climate models used in the USGCRP (2014) study project unprecedented warming across the entire U.S. with high confidence. None of the models agree on how much warming will occur. USGCRP projects an increase between $3^{o}$F and $15^{o}$F by the year 2100 depending on whether emission levels continue to rise or decrease by the year 2050. The minimum temperature change may lead urban developers to consider more green spaces in urban planning or increase insulation requirements in traditionally low insulation areas in order to improve cooling efficiency or impose stricter cooling guidance during peak periods to prevent rolling brown or blackouts.

The USGCRP projects with high confidence that as extreme precipitation events increase in frequency and magnitude across much of the U.S., flash floods will increase proportionally. According to USGCRP, flash floods are the leading cause of weather related deaths (p. 40). Understanding the risks of increased flash floods may lead planners to adopt better and more robust mitigation measures in their areas and engineers to develop durable but permeable surfaces for roads to further reduce flash flooding risks.

As wild fires frequency and intensity increases and development continues in and against woodlands, codes should reflect the increased risk and therefore mandate increased protection for those structures at risk. This change in requirements need not be implemented without discretion. Instead code requirements should target those buildings in and against forested lands just as flood protections such as pillars are targeted towards those at increased flood risk. This may serve to discourage increased development as well as provide increased protection to structures during wild fires. Increased protection should also be aimed at reducing the burden on fire suppression resources. This may current federal, state and local resources to stretch farther while private resources are used to protect private interests in wild fire hazard areas.

Maintaining status quo and depending on just the historical perspective fails to account for substantial changes that may happen within the service life of a given project. It makes little sense to build a levee or coastal barrier that will be overtopped as sea level rises. While existing processes have worked to date, anthropogenic climate change is accelerating and the historic only perspective is no longer viable given the long service lives of many structures.

Incorporating the minimum is better than adopting no change at all. Though scientists are still developing the tools necessary to increase prediction accuracy, emergency management professionals and those that assist them cannot afford to wait until those tools are developed before implementing changes. Failure to incorporate changes early may increase the number of people at increased risk due to lack of action. While this may drive mitigation costs higher, officials must consider the cost of pre-mature failure due to anthropogenic climate change as they weigh decisions regarding increased costs.

**Inclusive Policy Changes**

Policies must also be changed as the policies drive the standards. While policy makers habitually take notice of the emergency currently facing them, National, State, and local leaders must embrace a more strategic view of emergency management policies. Policies today impact structures built to last 50 to 100 years. Without policy changes, the ICC and others will find it difficult increase building code requirements under pressure from builders and others to keep costs down. Government leaders and their staff must take the first step in developing and implementing new policies that reflect the increased severity and frequency of natural hazards in the future.

Zoning practices should be changed in two ways. According to Tobin and Montz (1997), zoning practices are meant to protect the public from hazards but most zoning is currently based on socio economic reasons. Zoning needs to become a tool in hazard mitigation rather than a tool to keep the poor and wealthy separate. Once focused on hazard mitigation, zoning decisions must also include the potential impacts of anthropogenic climate change. For example, while some zoning changes may be phased in, others may need to be implemented immediately. Building a water treatment plant expansion in an area that may be submerged 50 years later needs addressed immediately while moving a pre-existing structure may wait until the actual change forces the move.

Officials may wish to include potential future hazards in their hazard disclosure process. This may discourage development in some areas, supplementing zoning decisions and reducing the burden later.

**Think outside the box.**

As population pressures increase and the climate continues to change, we must encourage innovation and open-ness to change. While people think of their ideal home today as a single family dwelling with plenty of room for their family and a beautiful green back yard, that ideal may need to change. Grass takes water. Water that may not be abundant in the future. Large houses and yards take space. Again, that space just may not be available in the future as the population increases to over 417 Million in the near future. Perhaps building upward rather than outward makes more sense. Officials could use incentives like shared property taxes for the same parcel of ground to encourage multi-story, multi-family dwellings to reduce the sprawl and control growth into hazard prone areas as population increases.

Does building downward make more sense in a particular region? While it would not work everywhere based on soil conditions, it may be feasible in some places. Building downward has some of the same benefits as building upwards with additional benefits in reduced heating and cooling costs. This would again require adjustments by the average homeowner to accept long term subterranean housing but may be an option for some with the right incentives.

As mean seal levels rise, perhaps researchers and engineers should look to develop ways to safely live on or in the oceans. Who knows what may be possible?

Living conditions are not the only areas requiring innovation. Adaptation and mitigation techniques must also move forward as the climate changes. Can genetic engineers develop plant strains that require less water? Can engineers develop a way to mimic photosynthesis to convert carbon dioxide to energy and oxygen making up for the damage caused by continued land development and wild fires while also providing a local and inexpensive energy source on every light pole? The list of ideas is endless but they require investment. A life changing development may never come to fruition if officials fail to see the value in investing in creativity and innovation.

**Future Research**

More research is needed to further explore the interaction between anthropogenic climate change and the profession of emergency management. Future research should focus on improving the responsiveness and services provided by emergency management professionals as they work to reduce risk in the face of natural hazards. While literature now addresses many areas, as can be seen in the data provided, much of the data must be refined and brought to an actionable level for practitioners to productively use. Research should focus on four areas:

1. Identify tools for practitioners in the field to reduce risk in the face of specific natural disasters encompassing planning, adaptation and mitigation.
2. Provide better data collection and repositories concerning tornado frequency and intensity in order to better inform emergency management officials of any potential for increased risk due to tornadoes in their area.
3. Provide a more comprehensive approach to anthropogenic climate change and emergency management bringing together multiple disaster types by region to enable more comprehensive decision making
4. Identify high payoff planning, adaptation and mitigation efforts that reduce risk against multiple hazards enabling better use of limited resources.

Lastly, as most researchers identify, continued research should focus on reducing the margin of change due to anthropogenic climate change. Reducing the uncertainty should result in better information regarding specific hazards in specific areas of the U.S. Greater specificity may also make the threat of increased risk more realistic than a broad range of possibilities that some may see as guessing rather than scientific study. Refining climate change models and outputs may contribute more than any other single research objective on the greatest number of fields.

In conclusion, most experts agree that anthropogenic climate change is already effecting climate nationally and regionally within the United States. Emergency managers and policy makers must work together to incorporate potential changes in natural hazard frequency and intensity due to anthropogenic climate change into planning, adaptation, mitigation and policy decisions today. Officials cannot afford to wait until these change are upon them before making the needed changes as many decisions today impact the adaptation and mitigation efforts that may be in place 50 to 100 years from now. Failure to make changes today may leave those emergency management professionals are charged to protect vulnerable to hazards of significantly greater intensity and frequency tomorrow.

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# APPENDICES

## APPENDIX A: LIST OF TABLES

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**APPENDIX B: LIST OF FIGURES**

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