The Ecological Effects of Hurricane Harvey and the Black Forest Fire on West Nile Virus

By Joseph Hueter, Mia Lagunas, Annabel Yarborough

Abstract

Extreme weather events are becoming increasingly frequent and destructive as a result of large-scale climate change, leading to changing environments for organisms ranging from the microbial level to the macroscopic level. The purpose of this research is to identify and analyze the ecological effects that extreme weather events, specifically hurricanes and droughts, have regarding the spread of West Nile Virus. In addition, by utilizing this study's data, we will form a data-driven hypothesis of the long-term effects of more frequent weather events on similar regions over time. Using GLOBE's Advanced Data Access Tool, disease reports created by the Texas Department of State Health Services and the Colorado Department of Public Health and Environment, NOAA Climate Monitoring Tool, and NASA's Land Assimilation Data Tool, we will conduct two case studies using Hurricane Harvey in Texas (2017) and the Black Forest Fire in Colorado (2012). For the former, we will focus on Harris County, Texas, and for the latter, we will focus on El Paso County, Colorado. For each individual case study, we will conduct a comparative analysis of the region utilizing data five years prior to and post each event as well as data gathered during the event period. The data collected will be analyzed through time series models and standardized anomaly indexes to determine the effects of the events on the soil moisture, precipitation, average temperature, air temperature, and West Nile Virus risk in the corresponding regions. From our research, we expect our findings to display the relative effects of each extreme weather event on the spread of the West Nile Virus with an overall increase in risk due to the creation of more habitable environments for mosquitoes in each respective climate.

Introduction And Review of Literature

As climate change is increasing at alarming rates, the direct links between a rapidly changing climate, more frequent extreme weather events, and West Nile Virus risk is not often made. One of the most vividly seen effects of climate change is seen through a series of disastrous weather events experienced in diverse areas around the United States. According to the World Meteorological Organization, in the last 50 years the quantity of natural disasters has quintupled as a result of climate change (WMO,2021). Additionally, the number of hurricanes is predicted to intensify throughout this century, urging researchers to analyze the direct effects of such events on human health (Juarez, 2008). Vector-borne diseases pose devastating consequences to different diasporas in human life, including declined health, death, and even economic downfall; a consensus conducted by the World Meteorological Organization reflected that related health care related to mosquito disease is estimated to be over 56 million dollars per year in the U.S. alone (WMO, 2021). In the United States, West Nile Virus is considered to be the dominant cause of mosquito-borne disease; its effects on humans ranges from very mild to fatal (CDC, 2019). As extreme weather events become more frequent, the risks of vector-borne diseases increase exponentially. For example, one study discovered that extreme flooding has been found to have a positive impact on malaria transmission in Uganda, leading to a 30% increase (Fouque, 2019). Similarly, a study on the increasing frequency of droughts as a result of climate change determined that over the next 30 years, increased droughts could significantly increase West Nile Virus cases by up to 30% depending on human immunity (Paull, 2017). Similar to the studies cited above, the research conducted within this paper analyzes the link between extreme weather and vector-borne diseases. In this report, we focus on the distinct effects two specific extreme weather events have on the risk and transmission of West Nile virus: hurricanes and droughts. This is essential to understanding the risk that humans living in similar regions face and how the effects of climate change will further increase these risks. The data analyzed in this report can give us insight into starting the process of creating solutions to a diaspora of different problems. Within this study, an array of meteorological variables bridge together to create an understanding that can assist in comprehending the effects of extreme weather events on human health.

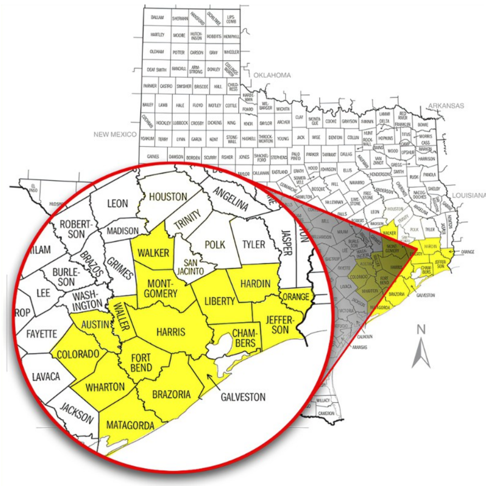
Research Questions

While the short and long-lasting effects of extreme weather cases are still being studied and analyzed, our study's research focuses on answering specific questions regarding the effects of two specific extreme weather cases. Our research questions, answered by analyzing GLOBE, public government data, and remote sensing data are: How do the meteorological effects of hurricanes and droughts affect the risk of West Nile Virus? How did Hurricane Harvey affect the spread of the West Nile Virus in Harris County, Texas? How did the Black Forest Fire affect the spread of the West Nile Virus in El Paso County, Colorado? The results of this study will indicate the consequences of increasingly frequent extreme weather events and a shifting environment as a result of global climate change. This includes the spread of vector-borne viruses, which pose a critical threat to humans. Furthermore, this study will contribute to a fundamental understanding of the effects that individual extreme weather cases have on our environment, and as a result, our health. Our study will help to bridge connections between meteorological data and understanding how extreme events affect vector-borne diseases. In order to establish patterns in this data, we will analyze variables affected by extreme events such as land cover, precipitation, average temperature, air temperature as well as West Nile transmission in two specific regions. The analysis of these patterns will aid in answering this study's research questions and can give us proper insight as to how mosquito ecology, in relation to West Nile Virus transmission, is being altered, and how it will look in years to come.

Research Methods

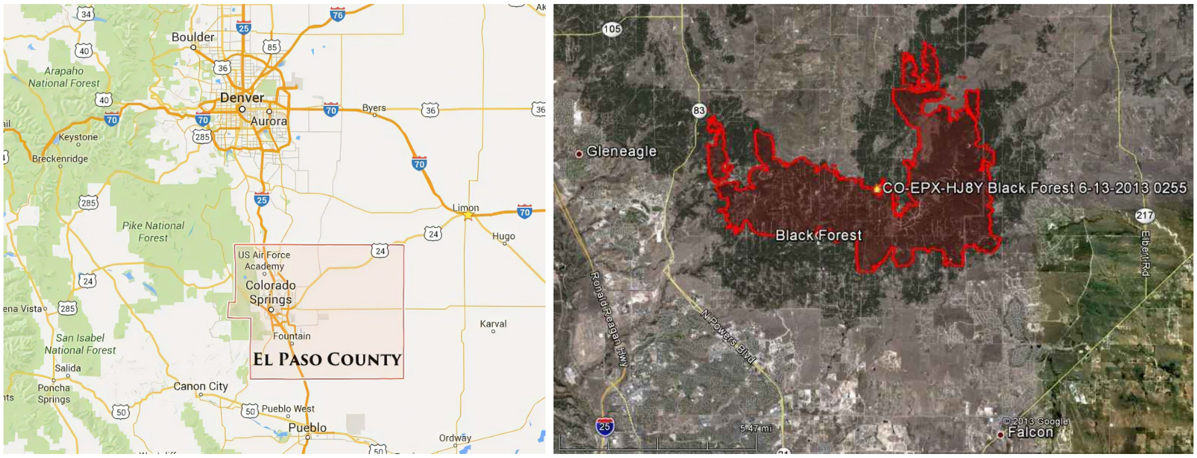
In order to evaluate and analyze the ecological effects of both Hurricane Harvey and the Black Forest Fire, we gathered data from the GLOBE Advanced Data Access Tool, Texas Department of State Health Services, Colorado Department of Public Health and Environment, NOAA's Climate Monitoring Tool, and remote-sensing data from NASA's Land Data Assimilation System. These expansive resources contained datasets regarding precipitation, soil moisture, air temperature, average temperature, and West Nile incidents, from our specified dates and study sites. Thus, we were able to directly analyze the correlations between the effects of two extreme events on the ecology of a region and the risks of West Nile Virus. For this research, we chose to conduct two case studies on two extreme weather events in vastly different regions of the United States. The first case study concerned Hurricane Harvey and its detrimental effects on Harris County in Texas. The second case study concerned the Black Forest Fire and its disastrous effects on El Paso County in Colorado. We opted to study one affected county for each event in order to gather more specific data on the short-term and long-term ecological and pathological effects.

Harris County is in the Upper Gulf Coast region of Texas and is characterized by its proximity to large bodies of water such as the Gulf of Mexico and Galveston Bay as well as its coastal prairie environment in its Southern sector (Henson). The climate of Harris County is typical for its proximity to the Gulf and the equator. The mean temperatures of Harris County's largest city, Houston, range from 53.8 F in the winter to 85.2 F in the summer with little variance in season (National Weather Service, 2022). Heavy precipitation is common in Harris County due to its location; its inhabitants are very familiar with tropical storms, hurricanes, and flooding. In terms of land cover, Harris County is 65.85% developed with 33.39% impervious surfaces; the large-scale development of Harris County has led to increased flooding and damage which has been exacerbated by the frequency of extreme weather events (Multi-Resolution Land Characteristics (MRLC) Consortium, 2022). For instance, in 2017 Hurricane Harvey, Category 4 on the Saffir-Simpson Hurricane Wind Scale, deposited 1 trillion gallons of water on Harris County leading to the worst flooding event in the county's history and affecting millions of residents (Harris County Community Supervision & Corrections Department, 2022). This study site will display the short and long-term results of Hurricane Harvey's flooding in Harris County on the spread of West Nile Virus.



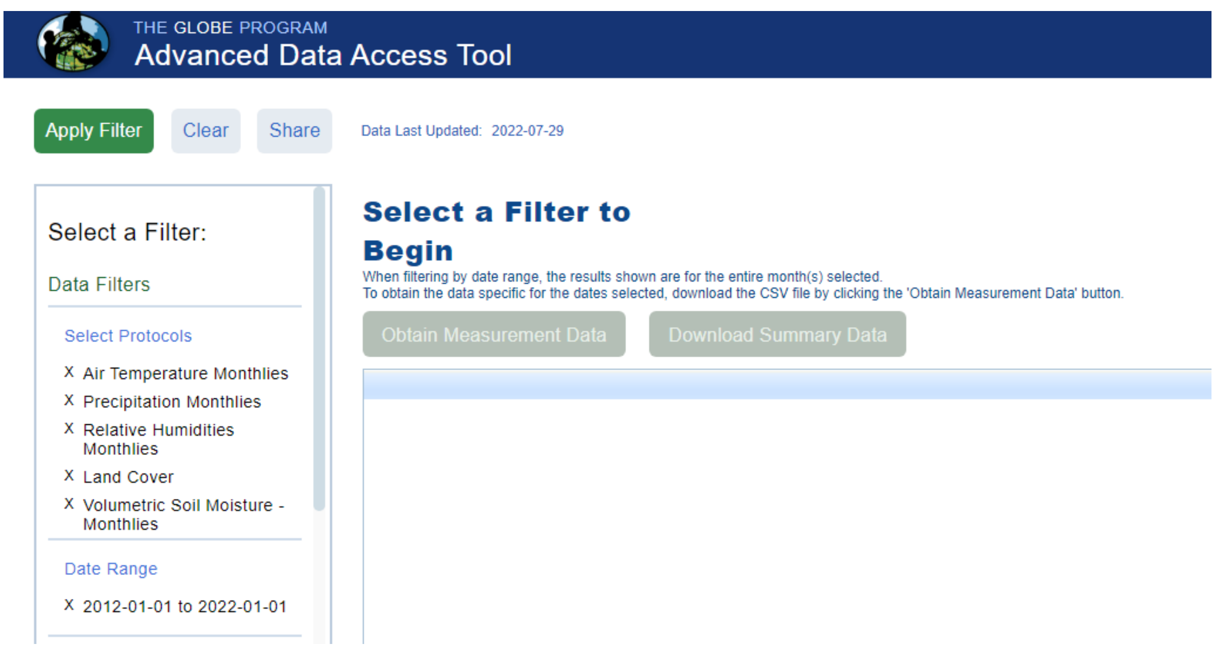
(Multi-Resolution Land Characteristics (MRLC) Consortium, 2022) ((Texas Gulf Coast Crime Prevention Association - TGCCPA - about Us, n.d.)

The second study site, El Paso County, is located in the Eastern region of Central Colorado and is characterized by its proximity to Pikes Peak, one of Colorado's main attractions, as well as its Great Plains environment and the Black Forest (Colorado Encyclopedia, 2022). The climate of El Paso County varies drastically by season and is dominated by cold winters and warm summers. The average temperature of El Paso County's major city, Colorado Springs, ranges from 18.5 F in the winter and 72.4 F in the summer. This region does not receive a lot of precipitation with the county experiencing frequent droughts and arid temperatures. In terms of land cover, El Paso County is somewhat developed with most of the population concentrated in Colorado Springs and the rest located in surrounding towns. Black Forest is one of these rural towns with 200 acres of land and a plentiful environment of Ponderosa Pines (Colorado Encyclopedia, 2022). In 2013, Black Forest was devastated by the most damaging wildfire in Colorado history; fortunately, it was contained quickly and precipitation increased before it spread beyond Black Forest. The importance of this fire is the conditions surrounding its spread, arid temperatures and low moisture, and their effect on the spread of West Nile Virus in El Paso County. The year prior, the entire state had been declared in drought and another devastating wildfire had struck the Waldo Canyon in Boulder County (cite drought paper, Ryan). This study site will give us insight into the effects of droughts on the ecology of El Paso County and the spread of West Nile Virus under these climatic conditions.



(Colorado Springs Archives, n.d.)

In order to assess the meteorological effects of these events, we first gathered data on each county's average temperature, average precipitation, average soil moisture, and average air temperature per month over 10 years. Originally, we included relative humidity and land cover in our protocols but inconsistent or no data existed. The data spanned five years before and after each event in order to evaluate the environmental context and the long-term effects. Therefore, for each variable, we collected a minimum of 120 data points. The first source we utilized was the GLOBE Advanced Data Access Tool (ADAT) where we selected the four protocols that matched our chosen variables. In order to gather information for specific counties, we input coordinates for each respective region and a radius that depended on the size of the county.



From GLOBE's ADAT we were able to gather relatively consistent air temperature data for both counties. We filled the gaps in the data by using NASA's Land Assimilation Data Tool, specifically the Giovanni database, in which we searched for air temperature data by using the coordinates of the GLOBE sites in Colorado and Texas. In order to acquire consistent average temperature and precipitation data, we used NOAA's Climate Monitoring Tool to gather monthly average temperature and precipitation data in each county. It was important to our analysis that the data had equal temporal resolutions so we had to incorporate data from other sources besides GLOBE. Our data analysis process revolved around creating time series models, analyzing each variable's change over time, and tracking anomalies. In order to account for seasonality and randomness, we removed the extrinsic trends from the data by calculating the difference between every two variables. From this point, we can align the time series models, as long as they are plotted on the same time scale, and analyze the changes in variables before and after each event. Additionally, to track the anomalies in the data, such as average precipitation over time, we calculated the standard deviation of the precipitation values, then calculated the difference between the average precipitation amount for the entire data collection period, and lastly, divided that difference by the meteorological standard deviation. This allowed us to create a standardized anomaly index model for precipitation and average temperature after Hurricane Harvey and the Black Forest Fire. This data analysis displays the significant changes in West Nile incidents and meteorological variables after the occurrence of Hurricane Harvey and the Black Forest Fire as well as the flooding and droughts that caused or resulted from these events.

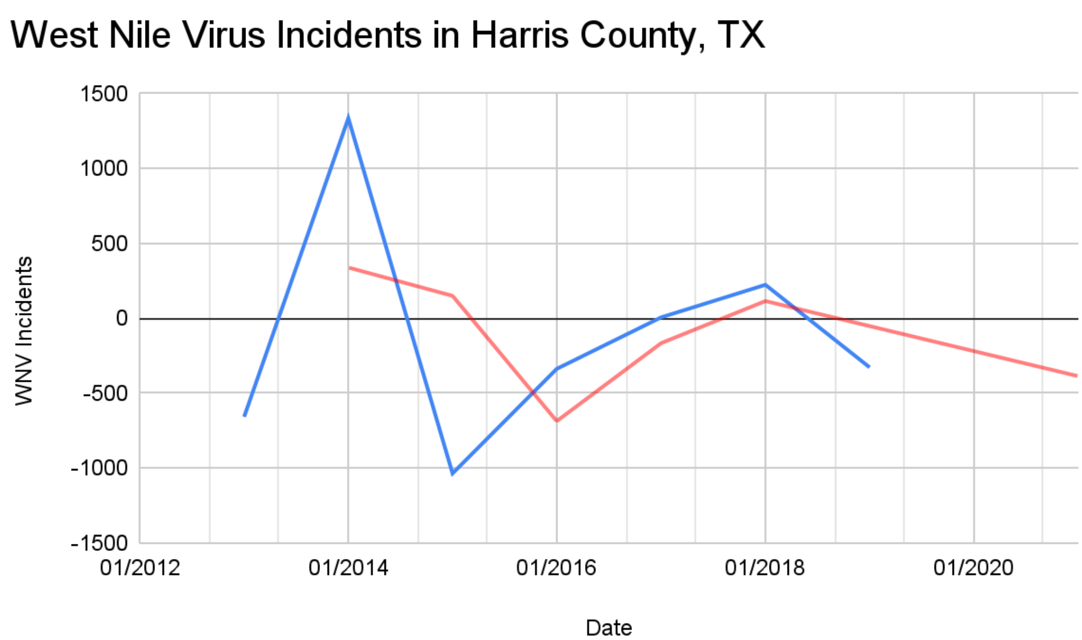
Results

After analyzing the data through time series models and utilizing a standardized anomaly index on certain variables, we can determine that Hurricane Harvey did affect West Nile virus incidents in Harris County, Texas. Additionally, we can conclude that the drought that contributed to the Black Forest fire affected West Nile virus human cases in El Paso County, Colorado. In contrast, the Black Forest fire itself did not have a distinct effect on West Nile in El Paso County; this result was affected by a discrepancy in West Nile virus data as Colorado does not provide information on non-human West Nile incidents.

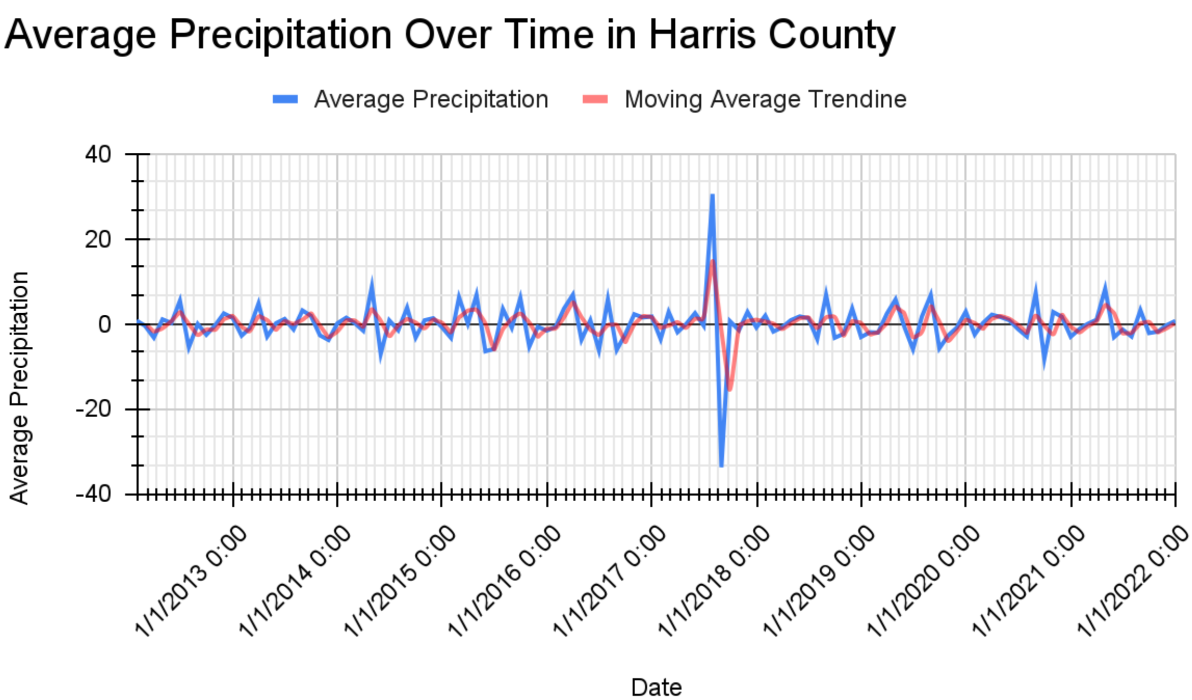
Beginning with Harris County, Texas, the effects of Hurricane Harvey are immediately clear upon viewing the precipitation data. A large increase in precipitation is evident during late August 2017, indicating the large amounts of rainfall that affected Harris County (Chart 2). The precipitation standardized anomaly chart indicates August 2017, has the greatest anomaly out of all ten years, thus showcasing the intensity of Hurricane Harvey on Harris County (Chart 3). Additionally, there is an increase in precipitation in 2018 displayed by the anomaly and time series graphs (Chart 2, 3). The Harris County West Nile virus incident time series chart indicates an increase in cases in 2016 from 2017, similarly, there is an increase in cases from 2017 to 2018

(Chart 1). This trend continues throughout the rest of the graph where years with many positive precipitation anomalies are typically accompanied by an increase in West Nile incidents. Soil moisture also rises significantly after Hurricane Harvey, specifically from August to September in 2017 (Chart 7). This also correlates with the increase in West Nile virus cases and average precipitation. In contrast to soil moisture and precipitation, the average temperature did not display adverse effects as a result of Hurricane Harvey, by viewing the time series model, average temperature remains in a consistent pattern and does not deviate during August 2017. Due to the consistency of average temperature in this region, if West Nile virus cases are influenced by this variable then it is likely due to seasonality and difficult to detect without a significant shift. We can infer, however, that warmer temperatures positively affect mosquito habitation due to preexisting knowledge about mosquito seasons. The data for air temperature had similar attributes, however, there is a slight pattern between extremely high temperatures and West Nile Virus incidents (Chart 8).

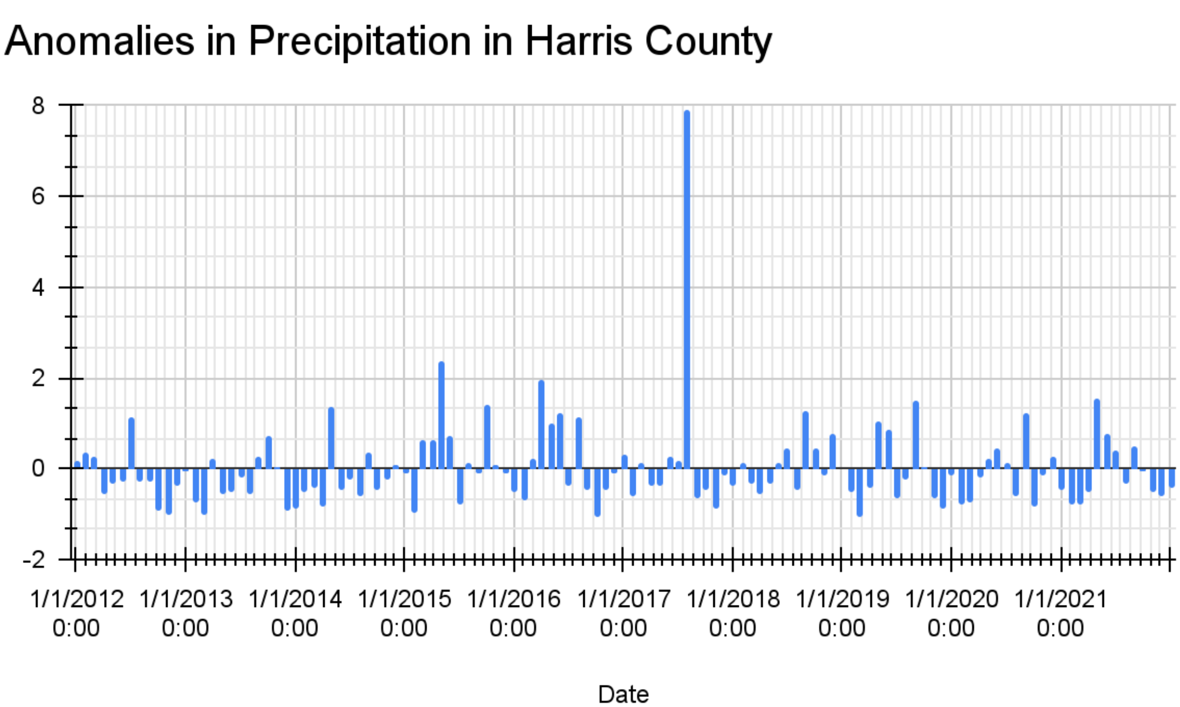
Texas Graphs:



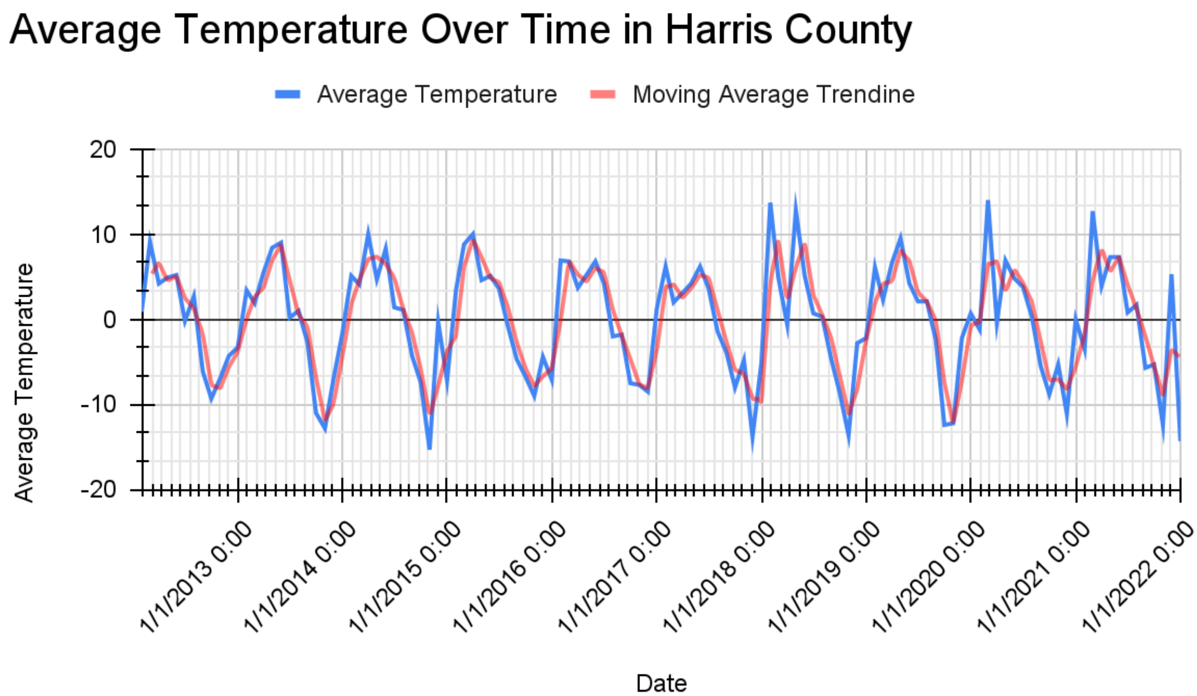
TX West Nile Virus: Chart 1



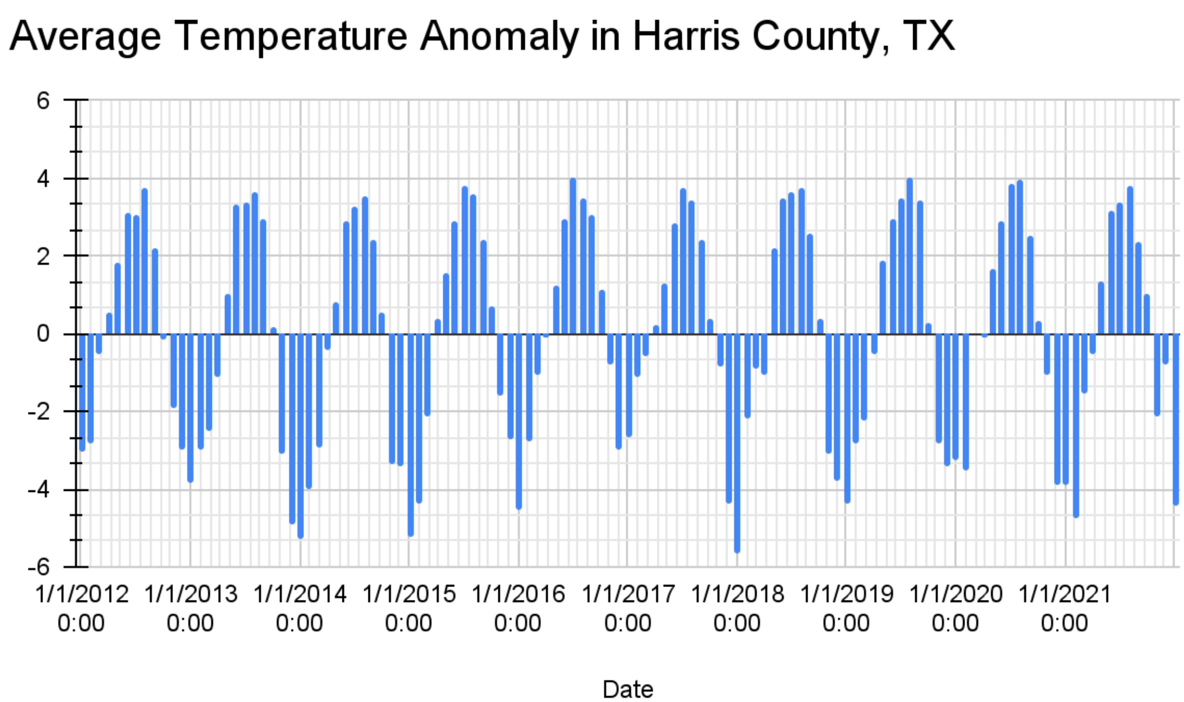
TX Precipitation: Chart 2



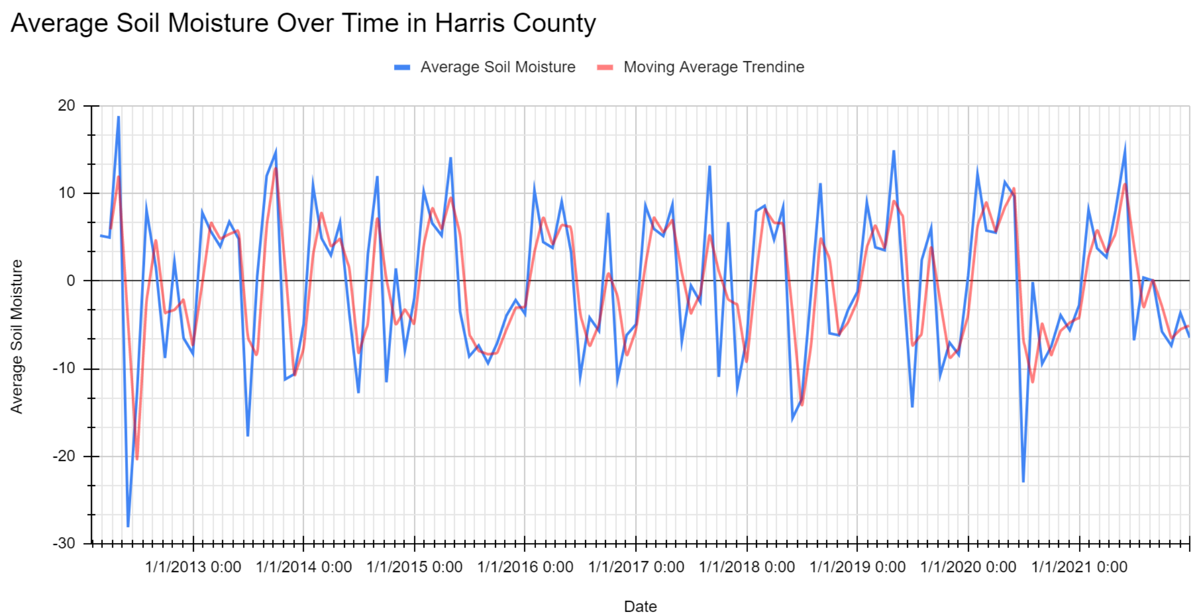
TX Precipitation Anomalies: Chart 4



TX Average Temperature: Chart 5



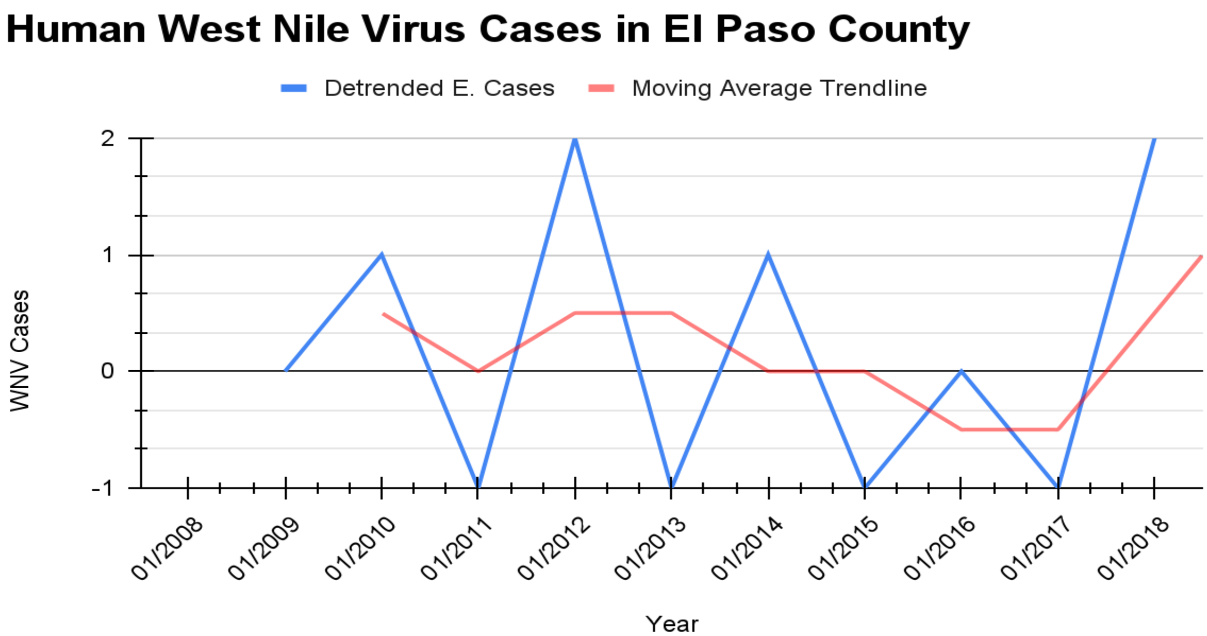
TX Average Temperature Anomalies: Chart 6



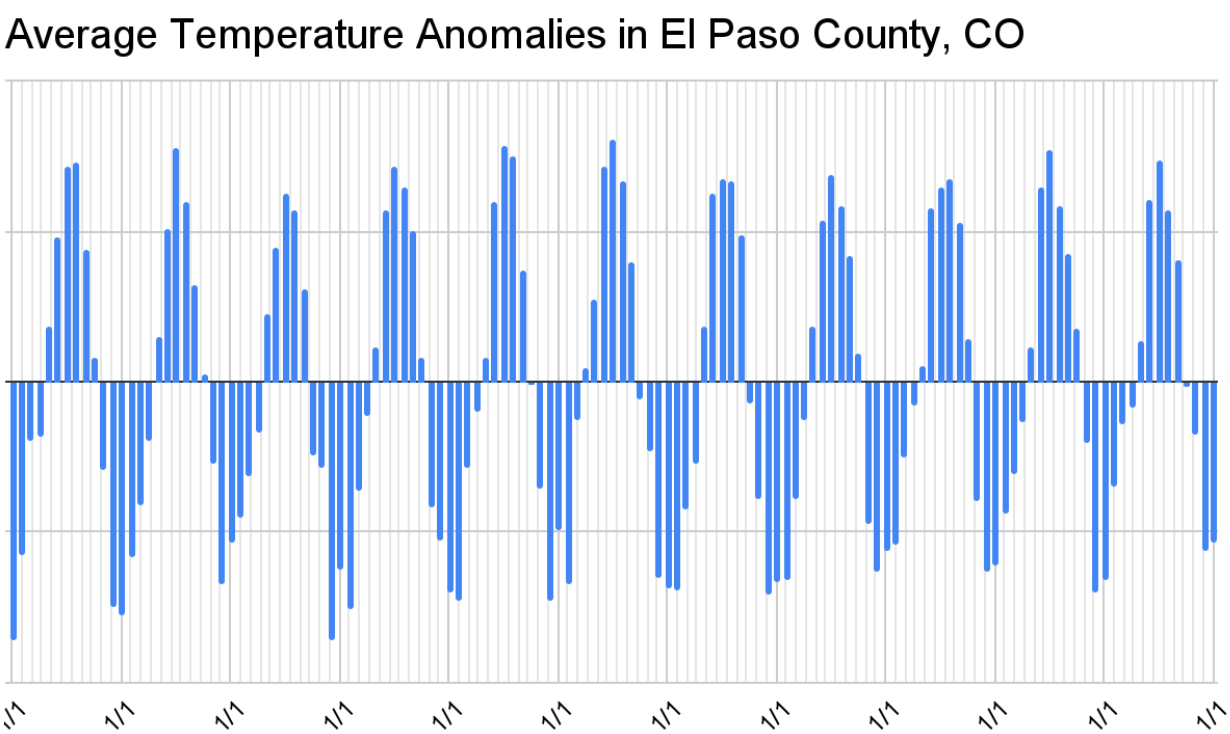
TX Soil Moisture: Chart 7

Similar to Harris County, the effects of the drought leading up to the Black Forest Fire are evident in the precipitation data for El Paso County, Colorado. Upon reviewing the time series model, the significant decreases in precipitation in 2012 correlate with the increase of West Nile Virus human cases in El Paso County (Chart 4). Additionally, decreases in average precipitation in late 2013 and 2014 also correlate with an increase of West Nile Virus cases in 2014 (Chart 1). Once again, the average soil moisture time series model is similar to Harris County in that it correlates to the precipitation and West Nile virus models; as the soil moisture decreases so does the precipitation yet the West Nile virus human cases rise (Chart 6). This negative correlation between West Nile cases and precipitation/soil moisture demonstrates the difference between regions of the United States and how they are individually affected by severe events. Once again, the average temperature displays a consistent pattern that deviates only slightly but not enough to correlate it to West Nile Virus cases. The results for air temperature differed, however, with a clear increase in heat during periods of drought in 2012 and the Black Forest fire in 2013 (Chart 7).

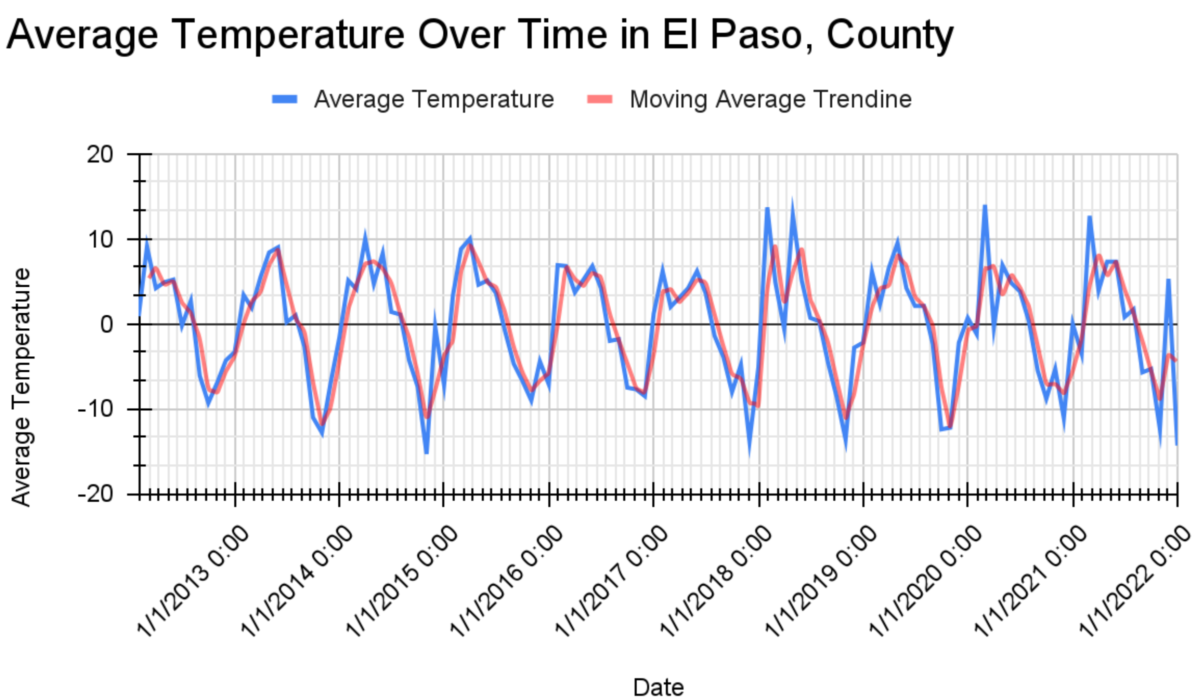
Colorado Graphs:



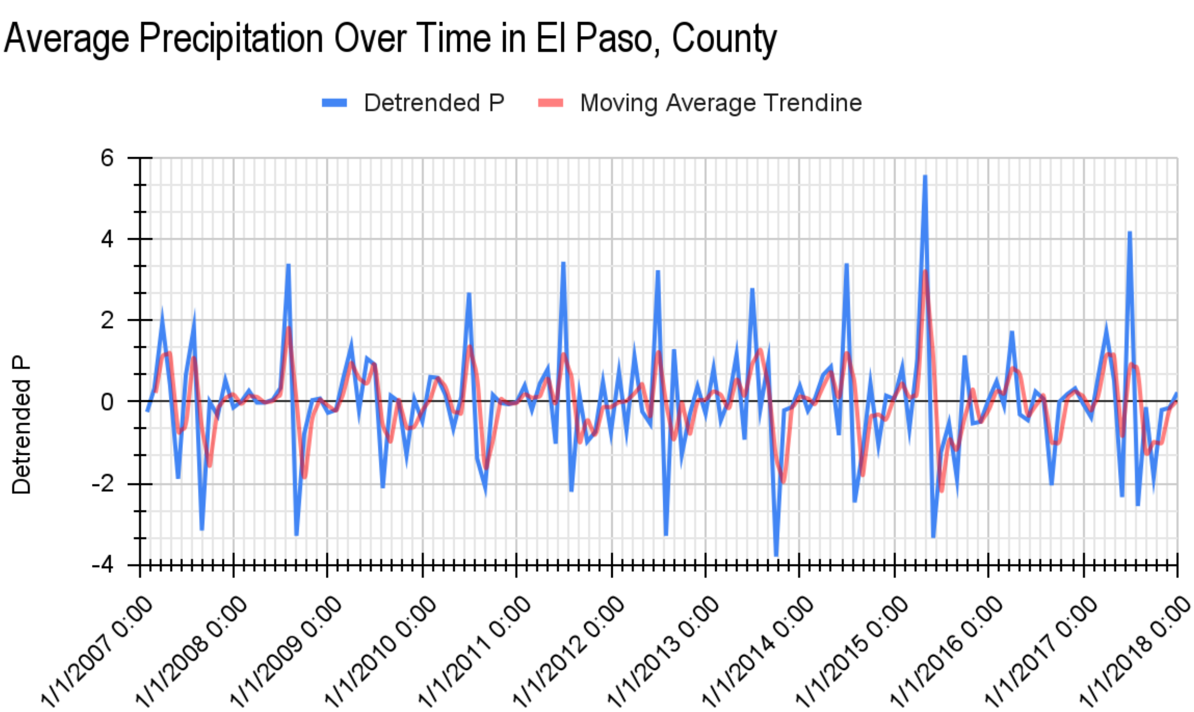
CO West Nile Virus: Chart 2



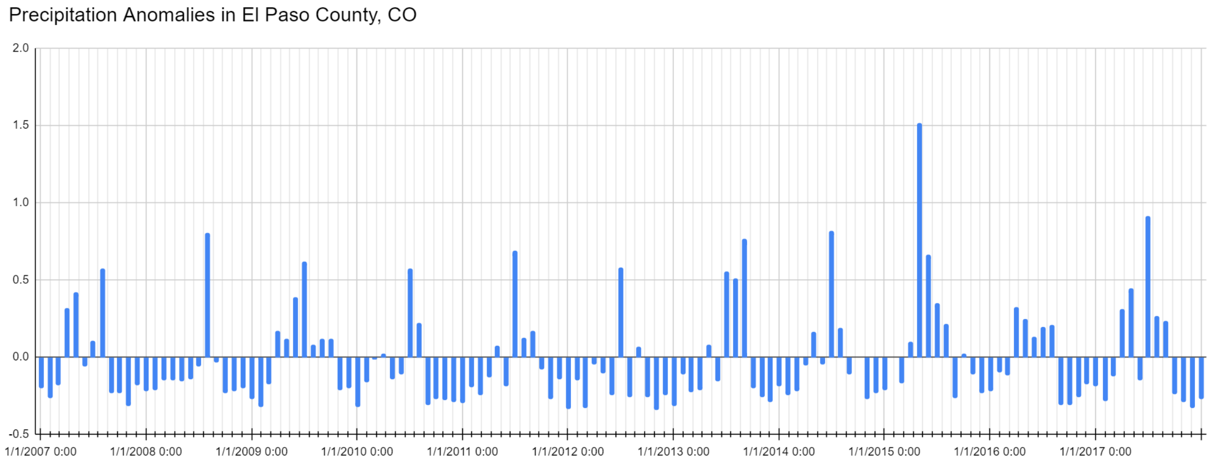
CO Average Temperature Anomalies: Chart 3



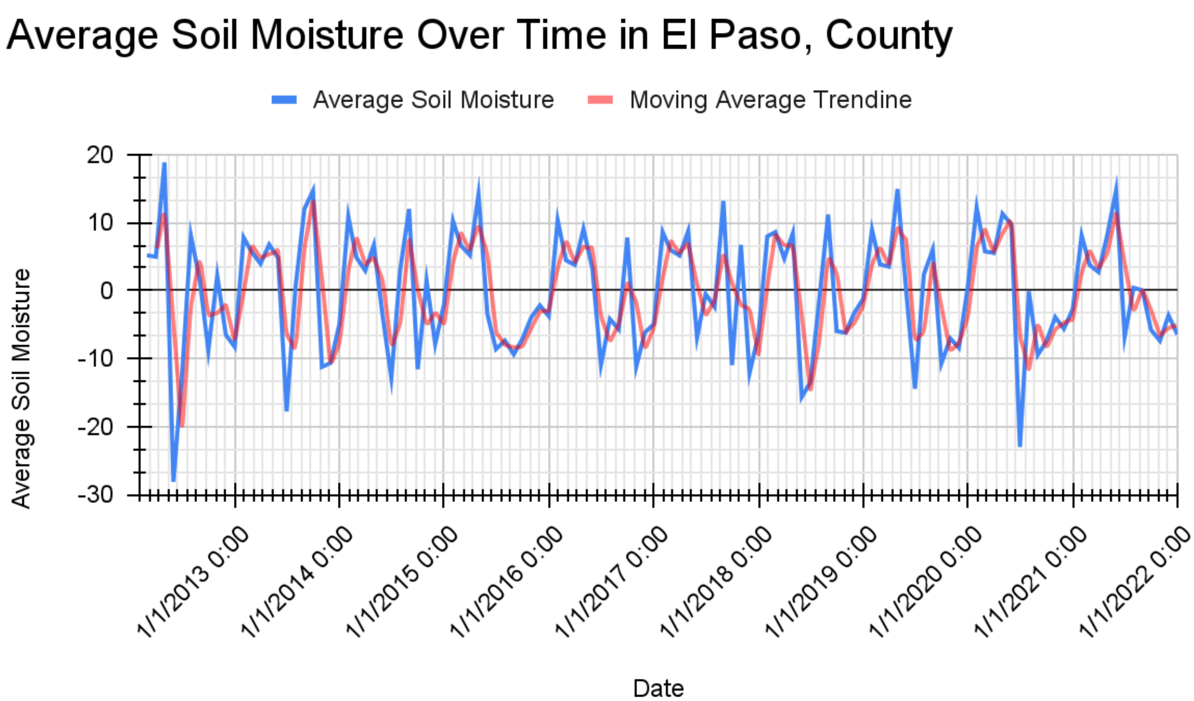
CO Average Temperature: Chart 3



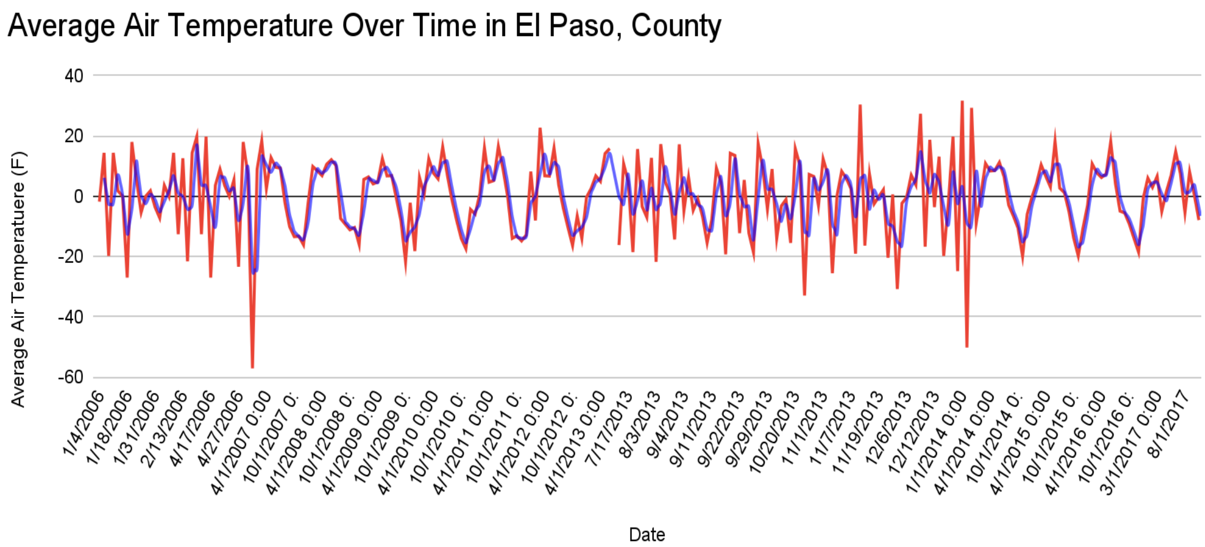
CO Average Precipitation: Chart 4



CO Precipitation Anomaly: Chart 5



CO Soil Moisture Over Time: Chart 6



CO Air Temperature: Chart 7

Discussion

These results reveal the significance of region and climate on a location's reaction to extreme events. For instance, we discovered a positive correlation between precipitation/soil moisture and West Nile Virus incidents in Harris County, but in El Paso County we discovered a negative correlation between precipitation/soil moisture and West Nile Virus incidents. This is likely due to the flooding after a hurricane which leads to more pools of water and the stagnant nature of water in a drought which also results in pools of water. Due to this analysis, we determined that regions familiar with arid conditions and droughts would experience increases in West Nile Virus risk as temperatures intensify and precipitation decreases. Additionally, gulf-coast regions that are familiar with tropical storms, hurricanes, and flooding would experience an overall increase in West Nile Virus risk as the frequency of extreme weather events increases. Our findings are rather consistent with peer-reviewed journals although the inaccessibility to certain data and our limited scope affected some aspects. For instance, in a peer-reviewed journal titled "Impact of Past and On-going Changes on Climate and Weather on Vector-borne Diseases Transmission: a Look at the Evidence", temperature is attributed to significant changes in mosquito habitats and is considered to be a major factor in the spread of vector-borne diseases (cite fouque). In our results, we found little effect from average temperature, which remained rather consistent over time. This discrepancy is likely due to the fact that we did not explore humidity in our data analysis. Although Texas's Hurricane Harvey did not immediately increase the West Nile virus (WNV) infection rate that is to be expected as the hurricane itself likely disrupted mosquito habitats, the result of the hurricane was more mosquito habitats were created from the abnormal precipitation. These new habitats increased the propagation of WNV amongst the mosquitos. The West Nile Virus incident data in El Paso County was difficult to analyze due to its inconsistency as well as the unavailability of data concerning all vectors and mammals affected by West Nile Virus. Without this complete dataset, it is difficult to predict the effects of droughts and wildfires on the risk of West Nile Virus. Some sources of error include other variables affecting our data such as mosquito population and disease control, population density in areas affected by extreme weather, and the effects of immunity to West Nile Virus.

Conclusion

At the start of this study, we sought answers to questions regarding the meteorological effects of extreme events, specifically droughts and hurricanes, on the risk of West Nile Virus. By conducting a time series analysis of four variables affected by such events (soil moisture, average temperature, air temperature, and precipitation), we determined that these events do directly affect the risk of West Nile Virus by creating more habitable environments for mosquitoes. Droughts and wildfires contribute to arid environments accompanied by stagnant water due to a lack of precipitation, both of these factors create environments that are more likely to attract mosquitoes. Hurricanes and floods contribute to damp and humid environments accompanied by pools of water thus also contributing to mosquito-friendly environments. As climate change leads to an increase in hot temperatures and extreme weather events, the increasing frequency of droughts and hurricanes will significantly affect the risk of West Nile virus regions similar to the Gulf Coast of Texas and Central Colorado. To further understand these effects, however, more meteorological variables should be analyzed, such as humidity, surface temperature, soil temperature, etc. as well as the risk of other vector-borne diseases after an extreme weather event. Furthermore, data on all incidents of a vector-borne disease should be tracked and made available in order to properly assess the risk of said disease.

To improve our methods, we could limit our scope to one type of extreme weather event and study its effects across different regions of North America or even globally. Additionally, more data analysis could have been performed, such as a forecast for more intense events. Overall, the experience of conducting research with mentors was very positive, it provided us with a helpful and experienced resource that could guide us through the process of researching and analyzing. dried areas around the country.

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GLOBE IVSS Badge Summaries

I am a Collaborator

The team has showcased the requirements to qualify for the I am A collaborator GLOBE IVSS Badge. Our team consisted of 3 members all placed around the country. Annabel Yarborough lives in Austin Texas but operated this summer from Colorado. Mia Lagunas lives and operates in Western Texas and, Joseph Hueter lives and operates from Southern California. Although the geographical distance did present barriers to the team. The difference in geographical setting allowed for unique perspectives to shine through, starting from the zoom meeting room to project decision-making, data collection and analysis of this report. Annabel Yarborough lead the team with respect to data collection and analysis in addition to logistics. Mia Lagunas aided with background and logistics as well as project formatting. Joseph Hueter specialized in project brainstorming and aiding with any additional tasks needed. The strengths of every member were used in the creation of this report. Their personality also shines within the fine lines of this report. Such as the decision of the type of extreme weather cases that are studied. The team was able to use their knowledge from different experiences and geographical locations to build upon theirs. While the team collaborated in this study they were able to encounter many areas of opportunity. This team did not only create a study that is beneficial and enticing to the scientific community but was able to support each other's growth in the respect to their collaboration skills and STEM knowledge and experience.

I am a Data Scientist

The team has showcased the requirements to qualify for the I am a Data Scientist GLOBE IVSS Badge. The team believes they have met the requirements because the study and report Include an In-depth analysis of collected data as well as referenced data sources. Data sources such as but are not limited to NASA GESDISC channel: Giovanni, NASA Land Data Assimilation System: NLDAS, and Multi-Resolution Land Characteristics (MRLC) Consortium. Within the report, the team discloses and reflects the limitations and barriers of our collected data and data process. However, the team includes insight on how our collected study data is a pillar to the continuation of studies that can help resolve and carry on the core mission of our project.