

International Virtual Science Symposium 2021

An Analysis into Phenomena in the United
States/Poles to Identify Trends in Extreme Weather

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Abstract

The purpose and context of this research was to investigate the foundations for increased extreme global climatic events and analyze its connections to the polar regions and how it affects the United States/world. In a time of great struggle, with global winter catastrophes and flooding destroying millions of homes, the research aims to provide insight and create connections through data analysis. A brief synopsis of some of the several research questions that guided the analysis and path of the research include:

- How does the Arctic region affect weather internationally?
- Why does global temperature increases create events of extreme cold?
- What weather phenomena can be correlated to the polar regions and what effect do polar regions have on them?

The main objectives of this research is to offer a view into the effects polar regions have across the world, and further illustrate the influences they have on weather phenomena. To obtain the conclusions derived, data from across the world was utilized to create graphs and improve existing models. Numerous datasets were obtained from NASA, NOAA, GLOBE, and more. Through the accumulation of datasets, connections from both a data science and analytical approach emerged. The results of the research indicate a great correlation between an increase in global surface temperature as well as a decrease in Arctic/Antarctic ice mass. The result of

this decrease in mass was found to strengthen extreme weather events, ranging from anomalies in the polar vortex to stronger hurricanes, floods, blizzards, and possible alterations in jet stream shape. The ultimate conclusion is that anthropogenic climate change is heavily affecting the polar regions, which proves vital in the regulation of climatic events on Earth. The path forward is to decrease greenhouse gas output to lower global temperatures, thus stalling the current path of environmental destruction and alteration

Keywords: Climate Change, Polar Regions, Extreme Weather Phenomena

Table of Contents

| | |
|---|-----------|
| Abstract | 2 |
| Table of Contents | 4 |
| Introduction | 5 |
| Hypothesis | 7 |
| Research Questions | 7 |
| Research Methods | 8 |
| International Virtual Science Symposium Badges | 11 |
| Study Sites | 13 |
| Texas | 13 |
| Arctic | 14 |
| Antarctica | 15 |
| Data Presentation | 16 |
| I. Graphs | 16 |
| II. Images/Figures | 20 |
| Data Interpretation and Analysis/Discussion | 24 |
| Hypothesis Comparison | 34 |
| Error Analysis | 35 |
| Conclusion | 35 |
| Future Research | 37 |
| Method Improvement | 37 |
| Mentor Impact | 38 |
| References | 39 |

Introduction

Throughout the world, concerns revolving around the frequency of extreme weather events are discussed, further ignited by “once in a million years” events appearing in the dozen each decade. During the past century, human activities have been fueling a rapid acceleration of pollution and thermal output, releasing large amounts of greenhouse gasses into the atmosphere where it envelops the Earth, enabling energy to be trapped and thus, causing global temperatures to warm. This warming has been correlated with the rising frequency of extreme weather, though many throughout the world continue to deny the mathematical relationships and correlations.

Research done by Kerry Emanuel(2017) utilized a computer climate model with greenhouse gas levels from more than 60 years ago to predict that an event with the same level of rainfall as Hurricane Harvey would only occur once every 2,000 years. However, by the end of the 21-century, it was discovered that the likelihood of an event similar to that of Harvey would only be 1 in 100 years with the current greenhouse gas levels. Furthermore, additional research by Stanford climate scientist Noah Diffenbaugh(2020) has indicated that rising global temperature is associated with widespread changes in weather patterns and ultimately, a greater probability of extreme weather events.

Research upon the field of extreme event attribution and additional frameworks has caused widespread utilization of event attribution frameworks and climate model simulations to further illustrate and quantify influences of anthropogenic contributions, though major links continue to be scarcely made or researched upon. Evidence regarding the link to global temperature increases to stronger storms has been generated, though not fully explained in regards to polar linkages and influences on atmospheric and oceanic systems. Additionally, minuscule research has been made regarding polar vortexes and influences on polar jet streams as well as extreme cold events, often outweighed in favor of research towards heat waves and droughts.

Research done by Bingyi Wu, Jia Wang, and John E. Walsh(2006) proposed connections regarding dipole anomalies in the Arctic atmosphere and its connections to sea level pressure and variance, though few extreme and definitive patterns have been identified in the context of cold events and stratospheric phenomenons.

The importance of this fundamental issue regarding extreme weather events and climate change as well as polar linkages cannot be understated, with more destructive events affiliated with changing polar conditions being experienced each year. Its ubiquity can be observed through events such as the February 2021 North American winter storm, where major and violent

winter/ice storms had widespread impact and resulted in over 170 million Americans experiencing various extreme winter weather events. Additionally, the extremity of this weather event and its weird fluctuations in the polar jet stream enabled Arctic cold to reach past Texas and into Mexico, causing the notable 2021 Texas power crisis. The relevance of this issue to the local and international community is ever more present, shaping and affecting the lives of billions due to the engendering of extreme weather events that continue to claim lives.

Hypothesis

The predicted theory behind the extreme events is climate change; to be specific, increasing global temperatures. A possible cause that may have intensified or created extreme weather events may be rising sea levels and depletion of ice in the polar regions.

Research Questions

Integral to the core root of this vital data analysis is if extreme weather events are a result of global anomalies in increased temperature as well as the declining area and extent of both the Arctic and Antarctic. The foundation to furthering research into the causes that engender extreme events that affect millions are inscribed within the question, and many others are held within its domain. How does the Arctic region affect weather internationally, why does global

temperature increases create events of extreme cold, and does the decline in ice cover correlate in any mathematical sense to the frequency of globally impacting climatic events? Such questions are cardinal in answering the world's various climatic dilemmas and advances a perspective into enveloping problems that have impoverished and killed several millions per year. Through the collection and analysis of data from several decades and centuries, such a trend can be identified, enabling scientists and students alike to further comprehend the broad range of implications. By researching these questions, important connections that penetrate every aspect of human life from both a geographical and climatic perspective can be advanced, further catalyzing additional research into methods of improving the situation that is fundamentally altering the Earth entirely.

Research Methods

The materials and software utilized for this research report include:

- iMac and Windows Desktop Computers
- GLOBE Data Access Tool
- GLOBE Visualization System
- Google Suite(Sheets, Docs)
- TensorFlow AI Models

- Keras AI Software Framework
- Microsoft Word
- Pandas AI Library, Numpy AI Library, Sklearn AI Library
- NOAA Weather and Climate Toolkit - Data Center
- Google Scholar

Data Collection Procedures:

Due to the massive nature of the questions and topics being investigated, large amounts of data were required in order for successful interpretation and analysis as well as custom-built software to aid in the process. To begin the data collection, data was gathered through GLOBE's Data Access Tool, which enabled the collection of data from schools in Texas in regards to air temperature. The GLOBE protocols utilized for data were Air Temperature Dailies, Air Temperature Monthlies, Air Temperature, and Air Temperature Noons. Upon downloading the data, the data was then imported and filtered into both Google Colaboratory for AI and neural network modeling as well as Google Sheets. Graphs and other displays were made to interpret the data in Google Sheets, enabling further research and investigation. From Google Colaboratory, predictive software was programmed and developed using Keras, TensorFlow, Pandas, Numpy, and Sklearn to predict future trends and train/test on data. Utilizing multiple artificial intelligence and machine learning models, such as Linear Regression, Logistic

Regression, Decision Trees, Naive Bayes, K-Nearest Neighbor, and Neural Networks(with varying internal hidden layers, nodes and diverse types of activation filters such as “softmax” and “ReLU”), AI software was able to be developed to further comprehend the predicted path the world’s climate was progressing in(both NASA and GLOBE data was fed in). As a result of the various AI models used, a diverse field of mathematics was applied into the analysis of the data, such as linear algebra, calculus, statistics and probability theory, discrete mathematics, multivariable calculus, matrix theory, and more. After this step, literature reading of several scholarly articles(i.e. Google Scholars, NASA, etc) and data sets obtained by satellites(such as ICESat) was used to further explain other atmospheric anomalies and identify mathematical trends. Additional data visualization tools were used to understand intriguing phenomena, such as weakened polar vortexes, and heavily altered polar jet streams(NOAA). Existing models were also identified and obtained from national and international government agencies in order to further explain and comprehend Arctic correlations to domestic weather.

International Virtual Science Symposium Badges

Badges Applied For:

I am a Data Scientist: This badge is being applied for due to the intense data collection of various resources and detailed interpretations. Additionally, the utilization of artificial intelligence that trained on the data to predict future pathways and aided in the progression of interpretation also required great data analysis. Predictions regarding the past and present for various climatic factors based on data from diverse sources additionally occurred. In-depth data analysis and collection was made on many climatic aspects such as global temperature, ice sheets, and more.

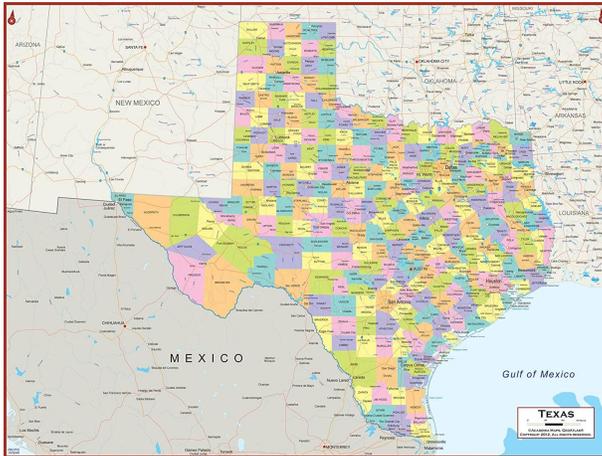
I am an Engineer: This badge is being applied for due to the utilization of student-generated data sources from across the nation to engineer a machine learning model that is able to predict real-world problems(increasing temperatures and more), and as a result, address changing impacts on the environment. This engineering design that utilizes multiple models helped solve solutions mentally as well, for it clarified trends that could not be identified beforehand. It aided in the creation of almost all trend lines discovered and aided throughout the discussion sections of the report.

I make an Impact: This badge is being applied for due to the creation of this research report being made to address the significant crisis that occurred in Texas, where extreme weather killed over 80 people and induced horrific conditions for those who live in the state. The issue regarding extreme weather and polar-induced extreme weather led to the research being done, and thus, could be utilized to address the dangerous issues of climate change and its effects on rare climate phenomena such as a weakened polar vortex. Through the many recommendations being made and the numerous connections and trends identified, the research will be able to explain confusing and indirect connections and offer a greater scientific perspective into the domain of extreme weather amplification and more.

Study Sites

1) **Texas**

- Map

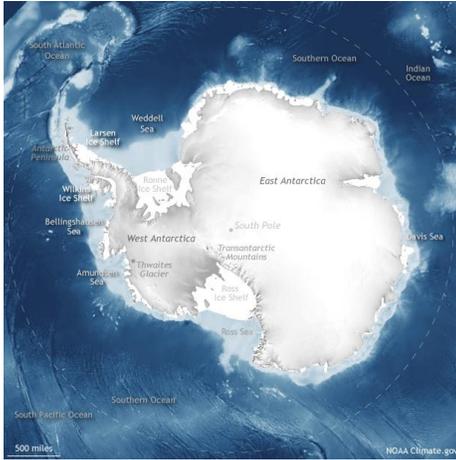


Description:

Texas is a state within the United States in the South Central region. It is the second-largest U.S state, with a total area of 268, 596 square miles. Due to its large nature, it contains 10 climatic regions, 14 distinct soil regions, and 11 ecological regions. Additionally, its various sections enable differing amounts of rain and snow, with the “Panhandle” of the state containing colder winters. A notable feature of Texas is its ubiquity in events such as thunderstorms and tornadoes, with the state experiencing the greatest amount of tornadoes in the United States. Hurricanes further inhabit the region, with the deadliest hurricanes spreading in Texas often.

3) Antarctica

- Map



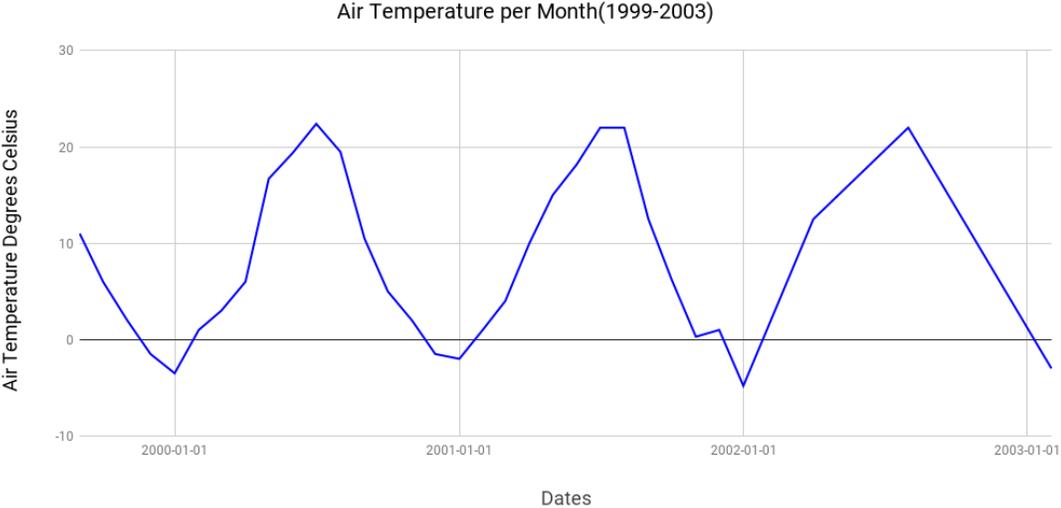
Description:

Antarctica is the southernmost continent of Earth. It lies within the domain of the geographic South Pole region and is surrounded by the Southern Ocean. The extent of the continent ranges around 14,000,000 square kilometers. Antarctica is a frozen desert, with only an annual precipitation of 7.9 inches. Across the continent, it is mostly (98%) covered by the Antarctic Ice Sheet, which averages around 1.6 km in thickness. Antarctica's climate is extremely cold, and experiences heavy snowfalls on the coastal portions of the continent. Other elements of the climate include aurora australis, which is a phenomenon that occurs near the South Pole due to plasma full solar winds. The average temperature within the interior of the continent throughout the year is around -57°C , with blizzards and other cold-climate events such as "diamond dust" occurring.

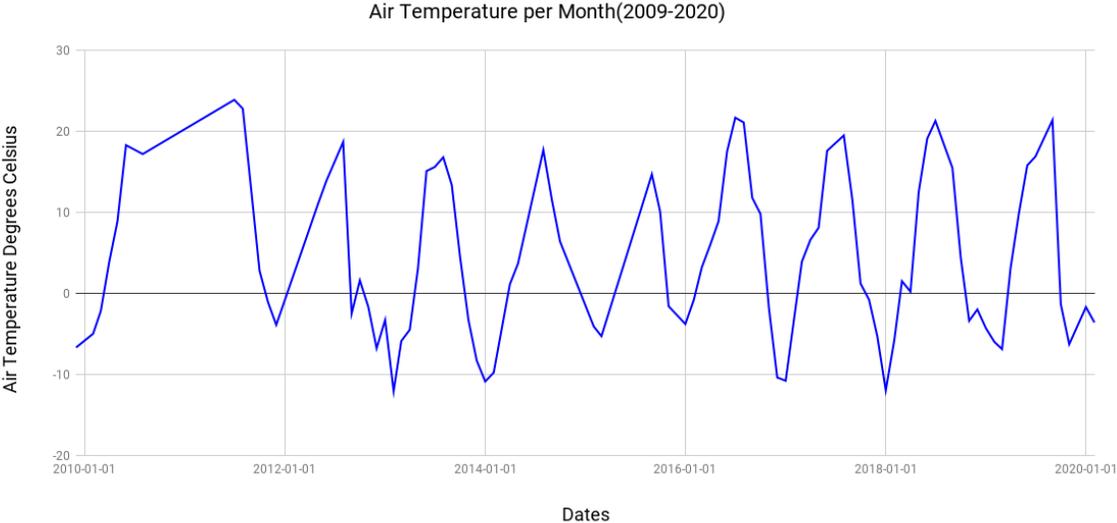
Data Presentation

I. Graphs

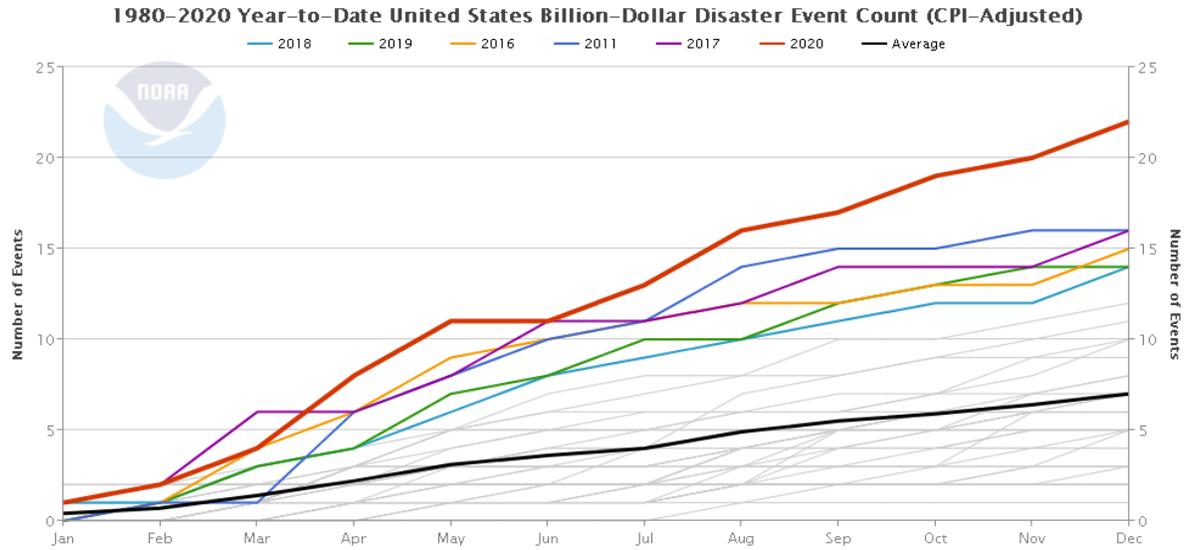
1) GLOBE Texas Data 1999-2003



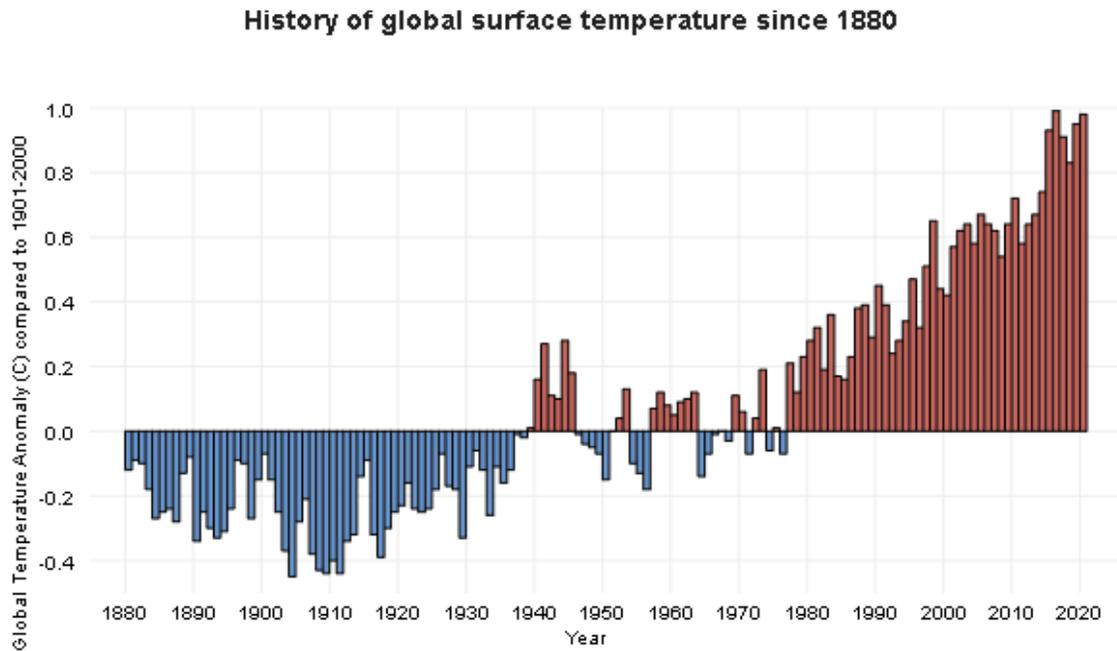
2) GLOBE Texas Data 2009- 2020



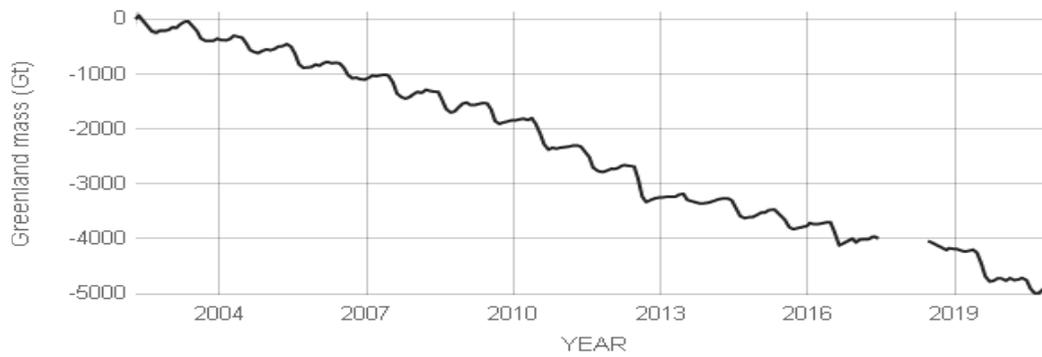
3) Extreme Weather Events



4) Global Surface Temperature

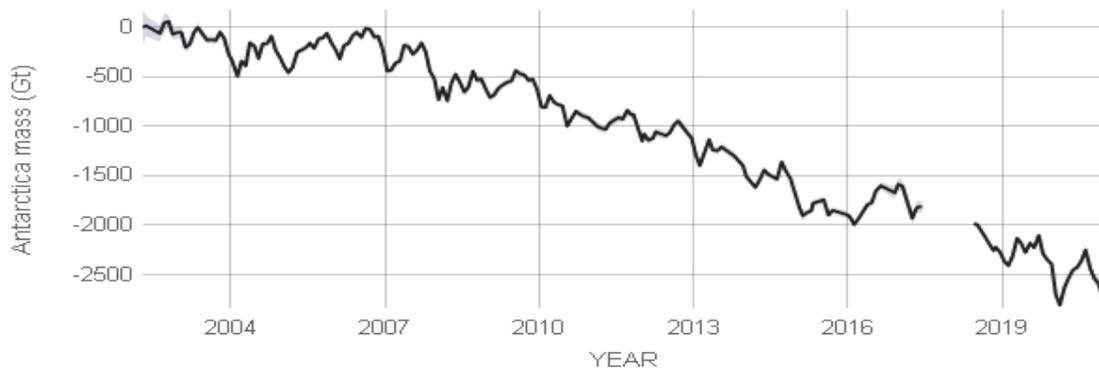


5) Arctic/Greenland Land Ice Sheets Variation



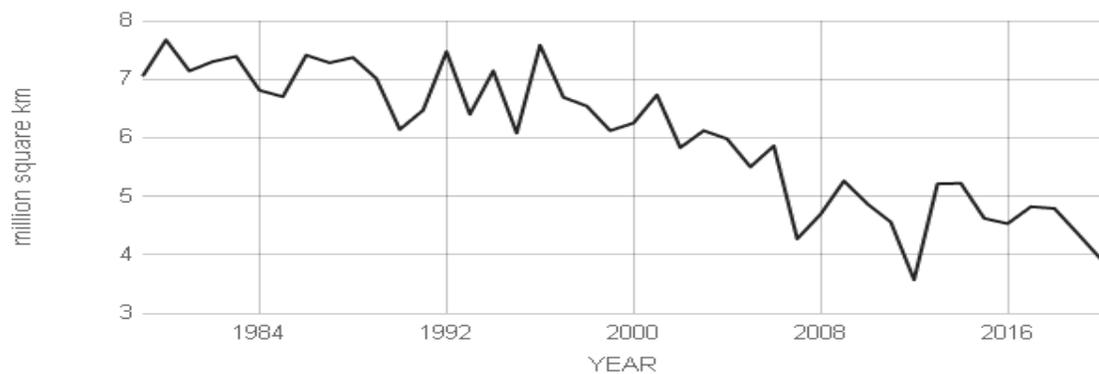
Source: climate.nasa.gov

6) Antarctica Land Ice Sheets Variation



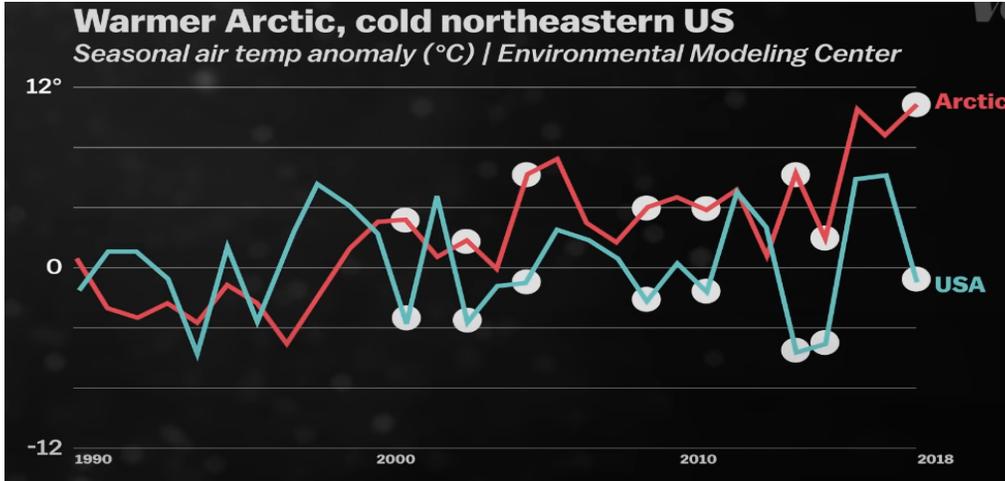
Source: climate.nasa.gov

7) Arctic Sea Ice Minimum

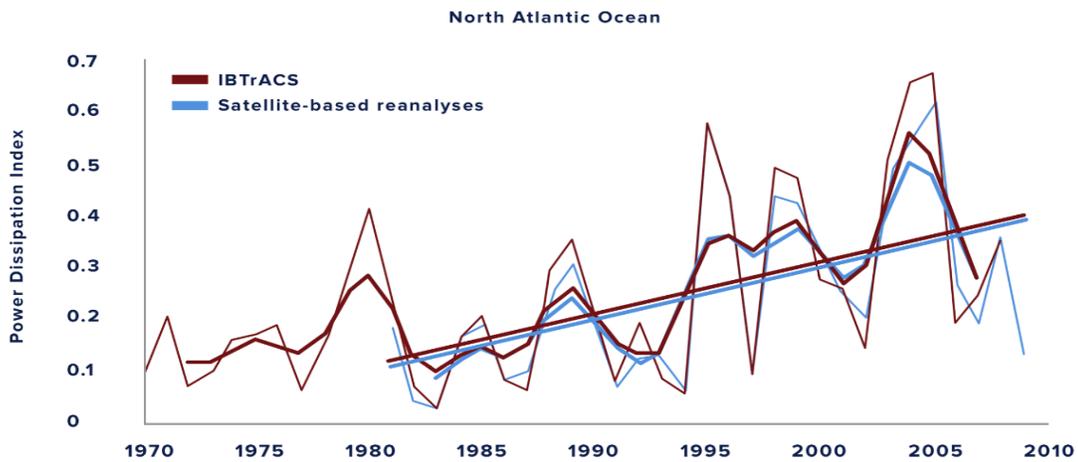


Source: climate.nasa.gov

8) Seasonal Temperature Anomaly in Arctic and Northeastern US

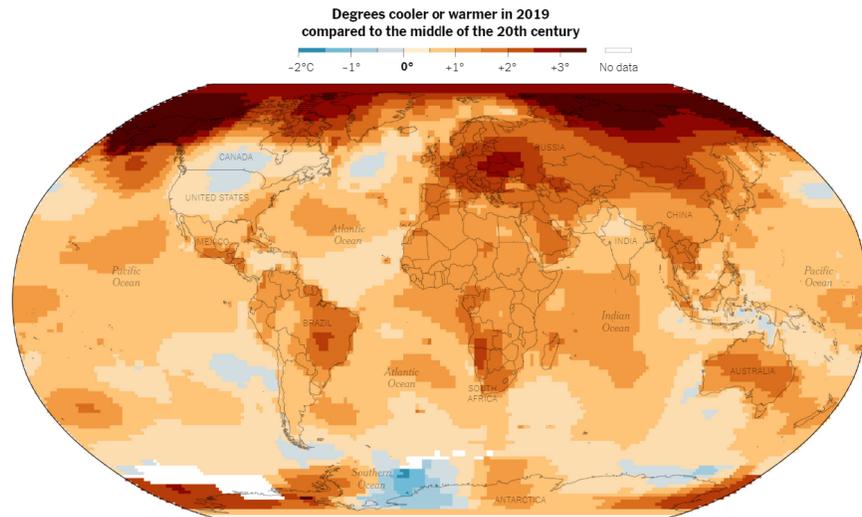


9) Growth in Power Dissipation Index for Storms in North Atlantic

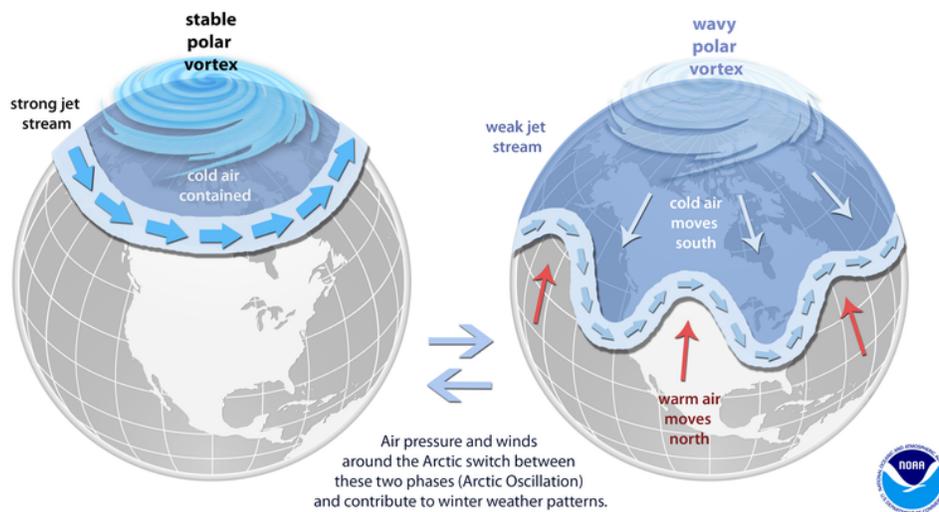


II. Images/Figures

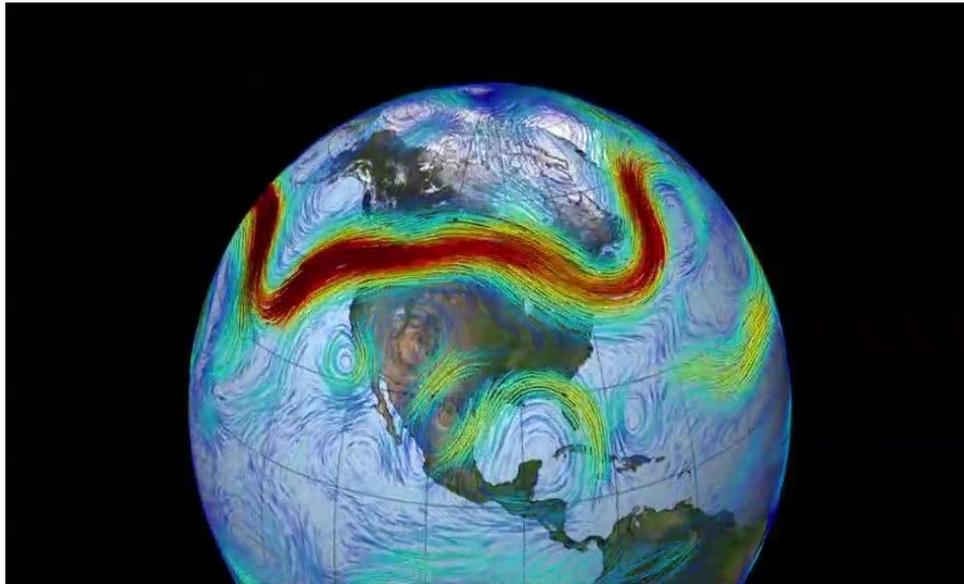
1) Global Temperature Variation Map



2) Polar Vortex and Jet Stream Variations NOAA



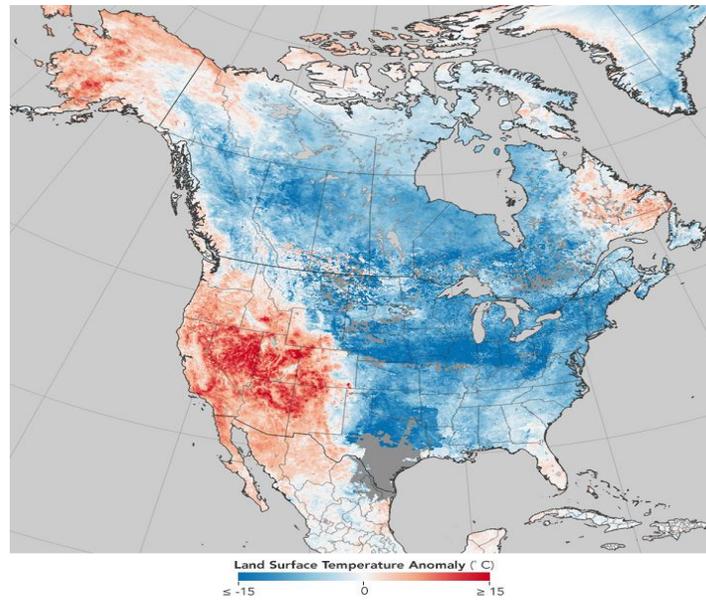
3) Polar Jet Stream Visualization



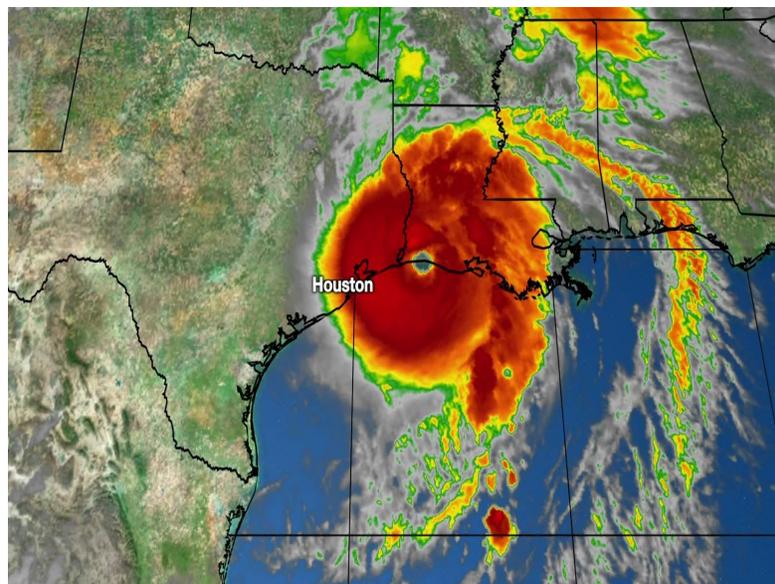
4) February 2021, North American Winter Storm Polar Jet Stream Dip Visualization- Texas



5) Land Surface Temperature Anomaly North America 2017



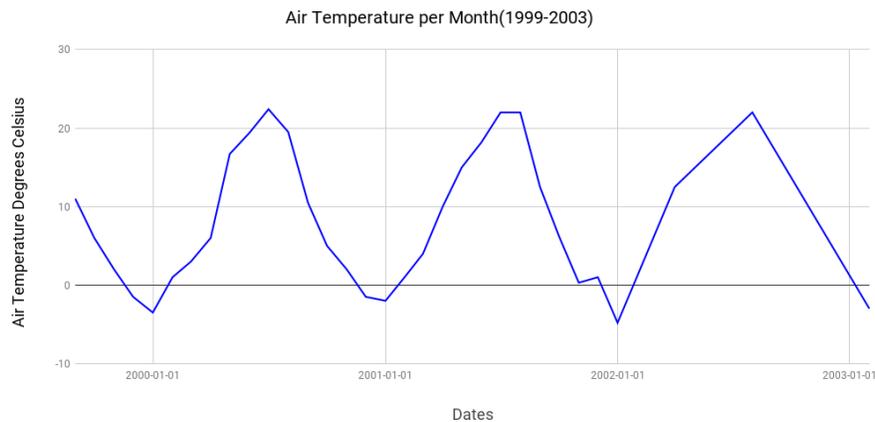
6) Hurricane Laura Texas Visualization



Data Interpretation and Analysis/Discussion

Exemplified within the data collected, it is evident that the increase in global temperatures has prevalence in its effects of global climatic events, often “contradicting” its overall trend(increase in temperature engenders frequency of cold events). A notable example can be witnessed in the state of Texas, known for its warm climate and moderate winters. However, as the international temperatures across the world have risen, the winters across the state have also increased.

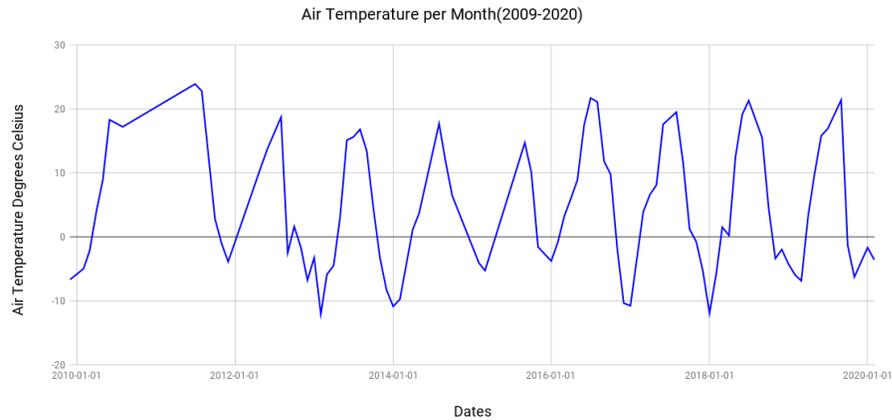
GLOBE Texas Data 1999-2003



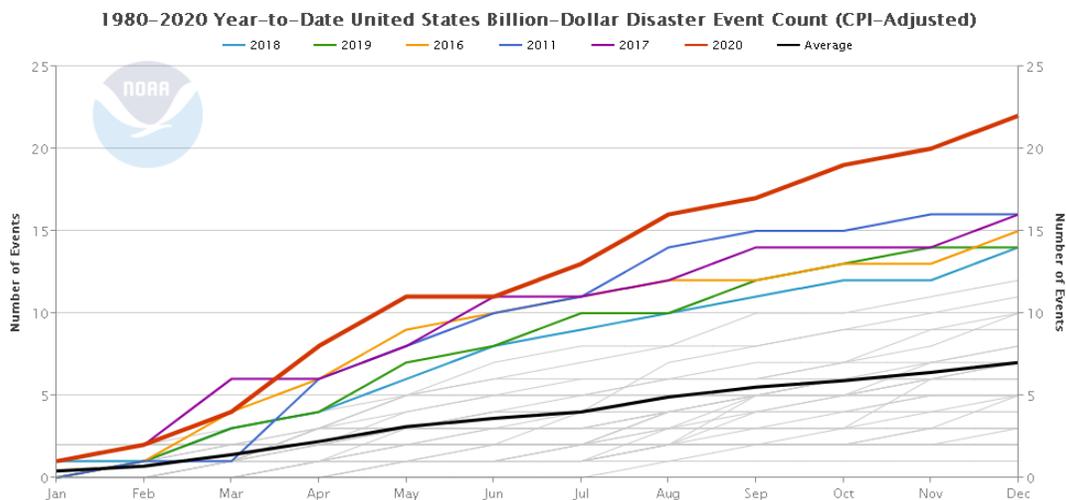
The averages of temperatures within each month observed from GLOBE Cuero High School(Texas) from the years 1999 to 2003 are illustrated above, with minimum air temperatures rarely extending past -3 degrees celsius in winters. As the years progress however, GLOBE data

from Ruth Cherry School(Texas) gathered in the recent decade illustrates a rapid scale of alteration.

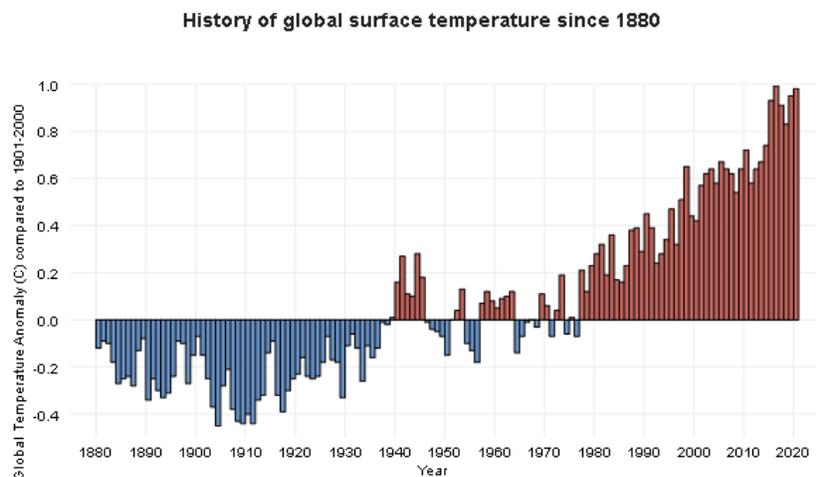
GLOBE Texas Data 2009-2020



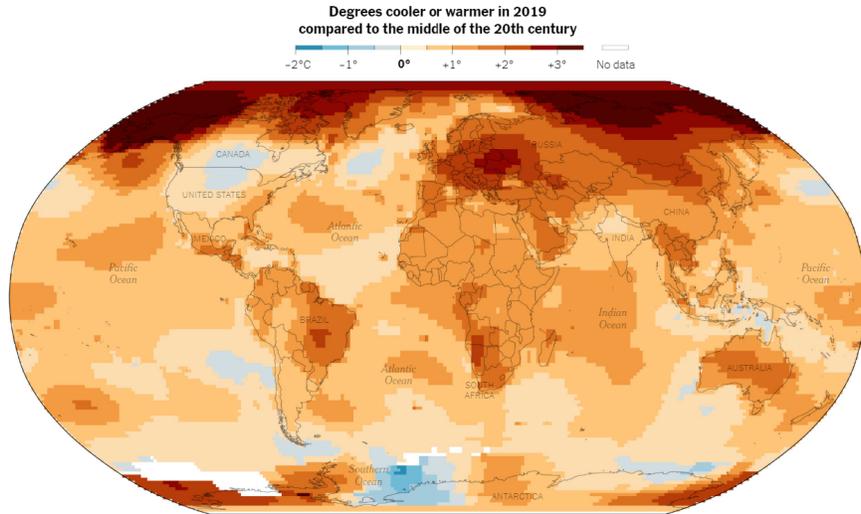
Both sites in similar climate regions of Texas, the sudden decrease extending to below -10 degrees is viewed, contrasting heavily from the prior trend identified. Snowstorms that were once spread across decades, have decreased to rates of around two years, as seen within the Texas winter storms of 2015, 2017, and 2021.



When graphing data gathered from NOAA, it is evident that extreme weather events within the United States itself are increasing profoundly, with the year of 2020 experiencing the greatest amount of destructive events recorded since 1980. Comparing it to trends in international temperature anomalies, a similar positive dramatic curve can be observed.

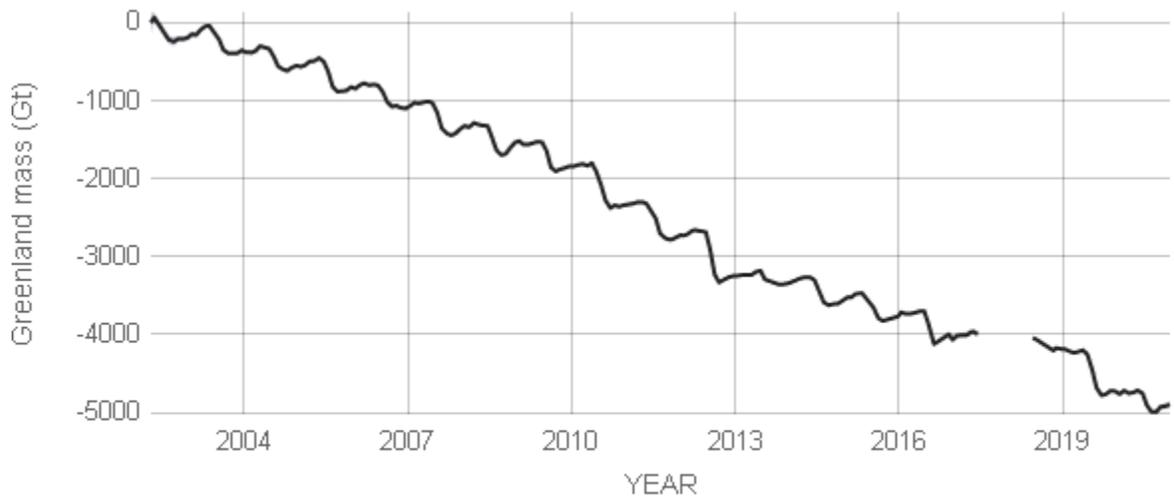


Consistent across both graphs, increases in anomalies and events of great magnitude are proportional, illustrating the deep connections between global temperature and extreme weather events. Additionally, global temperature anomalies are found greatest in the regions of the Arctic, demonstrating the possible impact fluctuations in temperatures of the Arctic may have in the events(particular cold events) observed throughout the world.



Visualizing the decrease in polar ice sheets every year in the Arctic, a profound and predictable change can be mapped further, correlating increases of disastrous events/blizzards with decreases in ice sheets.

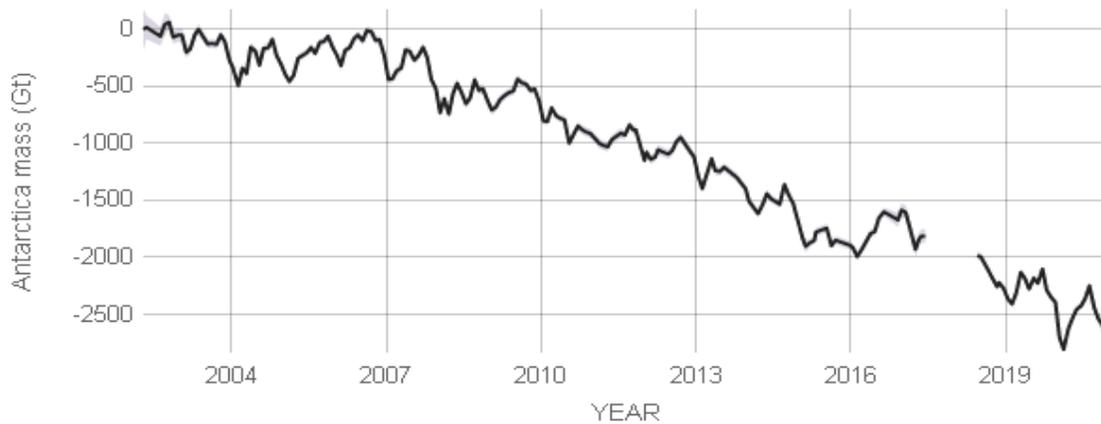
Arctic/Greenland Land Ice Sheets Variation



Source: climate.nasa.gov

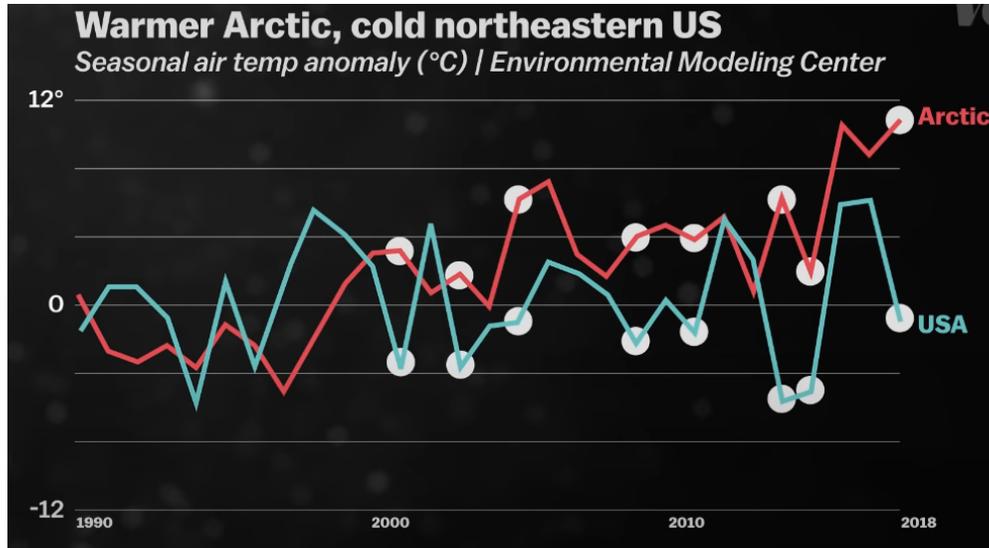
This concept cannot be only applied to the northernmost region of the Earth, but additionally to the southernmost region. Though not often common thought across the world, the continent of Antarctica is additionally experiencing great loss in mass and size, contributing to rising oceans and a possible cause of the global climate events that occur across the world.

Antarctica Land Ice Sheets Variation

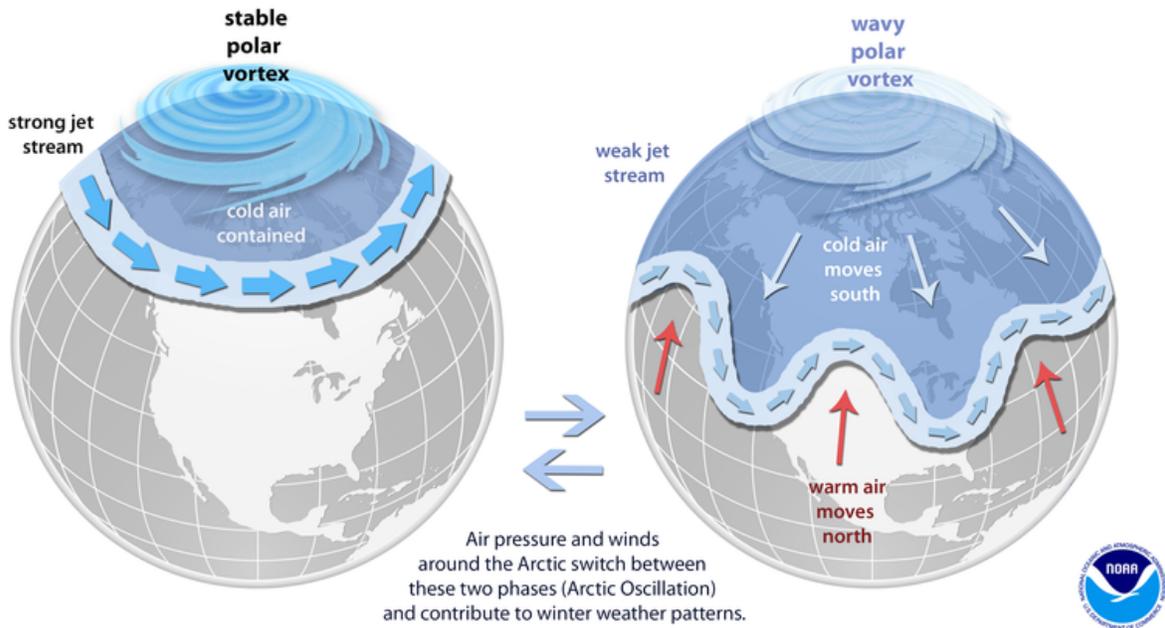


Source: climate.nasa.gov

With the identified and established correlation between national weather events and increasing global temperatures defined, a linkage between the Arctic region's weather and temperature anomalies can be compared to that of the United States's temperature and atmospheric winter events.



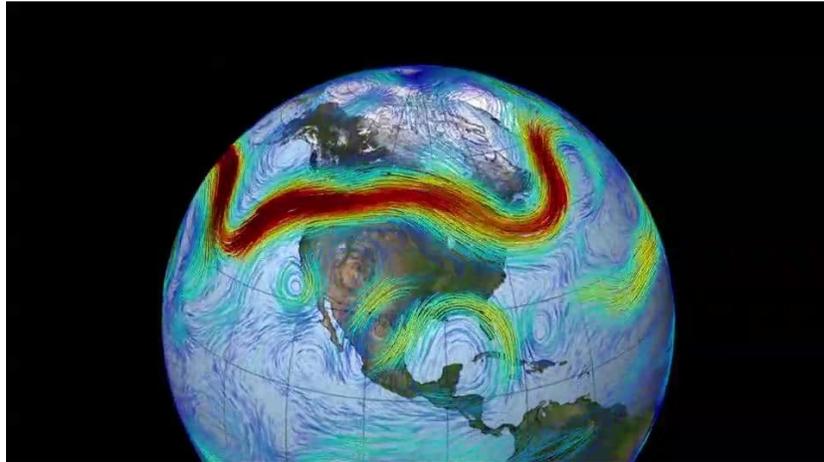
Plotted and visualized within the graph, a correlation between cold temperature fluctuation within the Northeastern United States and warm air fluctuation in the Arctic can be identified, signaling a possible thermal equilibrium in climate. To elaborate, as the Arctic experiences greater temperatures in heat, the difference (gradient) in heat/temperature between the United States and the Arctic is decreased, causing the stratospheric polar vortex to weaken. The polar vortex is a large low-pressure area of cold air that surrounds both poles (the North Pole is concentrated on in the context of this analysis). As a result of this weakening, the polar jet stream that lies below the polar vortex is additionally weakened and abnormal (unpredictability in curves), meaning the barrier that once separated Arctic cold air from reaching the United States and warm tropic air from reaching the Arctic is fluctuating enormously.



Though this is a hypothesis (in regards to the gradient and its effects on the polar vortex), its truthness can be found in recent events, such as the February 13 - 17 North American Snow Storm. Through data analysis, trends and inverse mathematical relationships further support this theory, possibly indicating an additional effect global warming and human pollution output may be contributing to. When accounting for the physics of earth and the chemical properties of hot air in the equator, an additional theory can be proposed and viewed.

To begin it is vital to comprehend the creation of wind. Wind is formed as a result of the uneven heating of the Earth's surface by the sun, where warm air that lies near the equatorial region moves towards the poles. To elaborate, as a result of hot air occupying more space (greater energy), the equatorial region's atmosphere is more "thick" and "taller", causing gravity to pull

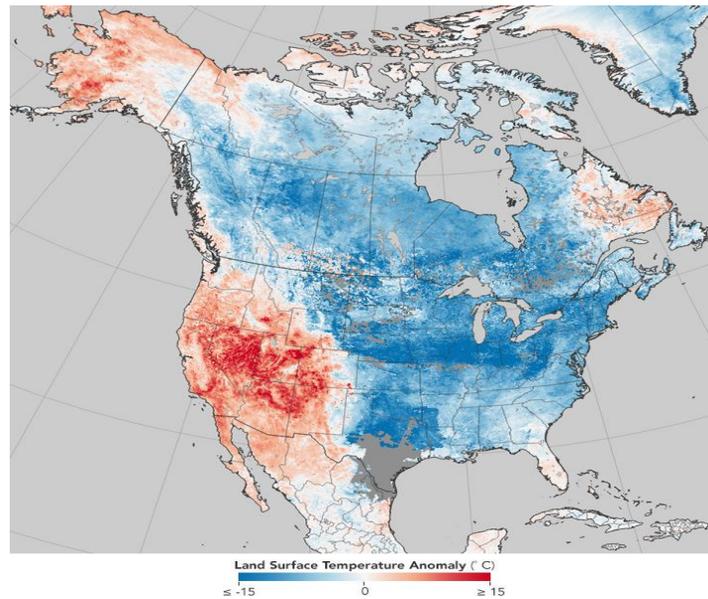
the air towards the Arctic due to it containing a thinner and shorter atmosphere, thus creating wind. Since the Earth rotates, a stream of wind in the form of a jet stream is created, moving west to east.



However, as a result of increasing temperatures in the Arctic, the jet stream becomes further curved due to a decrease in gravitational pull placed upon the Arctic (thickness of air increases within the equator and anomalies disturb gravitational pull upon the Arctic). This results in allowing cold air to reach extremely far south, extending the border of the cold air held above the polar jet stream.

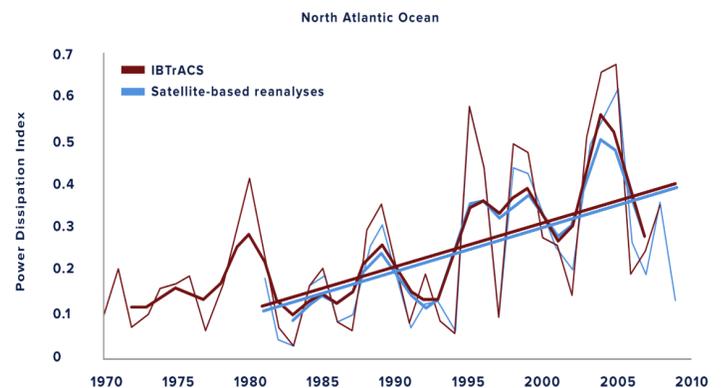
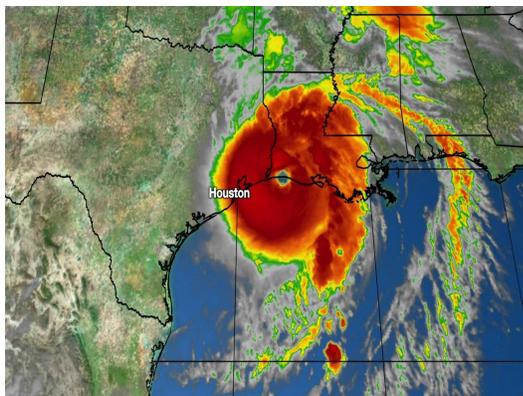


Inversely, the opposite additionally occurs, with a notable example being Alaska in 2017, where the jet stream brought hot tropical air and enabled Alaska to have its warmest average December on record.



Additional factors regarding the connection to Arctic weather and extreme weather events across the world can be tied into the concept of the jet stream, for due to increasing temperatures within the Arctic, more “wavy” curves form, producing dangerous effects for the storms that follow them. To explain deeply, reduced temperature difference between the North Pole and tropics is correlated to slower west to east jet stream movement and greater north-south dip in its path(as conveyed previously), which enables storms to stop/move slower and intensify, producing more extreme weather occurrences and destruction. Such examples of events produced by this anomaly are droughts, floods, prolonged cold temperatures, and heatwaves.

Extreme weather events, such as hurricanes, can also be correlated to the decline in ice from a scientific and analytical approach as well. Due to both the Arctic and Antarctica facing extreme ice loss, with massive glaciers breaking off and inevitably melting (a notable example occurred on February 26, 2021, where a glacier broke off of the Brunt Ice Shelf with a total size of 490 square miles - over a hundred more than that of New York City), more water is being added, thus rising sea levels. As this water circulates around the world through ocean currents, it increases the amount of water that lies within hurricane “fueling” regions. The additional factor of rising global temperatures further rising water temperatures provides increased energy to hurricanes as they draw greater amounts of energy from the warm ocean water. This effect can be viewed by Hurricane Laura, which quickly and profoundly gained strength over 90°F water within the Gulf of Mexico.



Referencing back towards the concept of rising sea levels as a result of the melting of the Arctic, other extreme events, such as flooding, affect regions across the United States and the world, with more storm surges being ubiquitous in poor and densely populated regions. Research

gathered by the World Resources Institute conveys that over 147 million people were heavily hit by floods annually, compared to only 72 million people in the previous decade, correlating to evidence of an immense decrease of both Arctic and Antarctic ice. From a national perspective, between the years 2000 and 2017, tidal flooding has increased by over 233% nationally (NOAA). Collective throughout the data obtained over all aspects of climatic events, a vital connection can be made, demonstrating the extreme significance the Arctic and Polar regions have on the entirety of global climate and life itself.

Hypothesis Comparison:

Through the results discovered, it is evident that the results closely correlate to the hypothesis. The prediction that rising global temperature intensified extreme weather events was correct, though lacking in evidence and connection until the polar explanation was found and introduced. The assumption of the possible causes for the creation/intensification of weather events was due to rising sea levels was false in the grand context of weather events (though true in regards to events such as floods). Rather, the assumption of the depletion of ice in the Arctic proved more true when comparing to the results, though for more indirect reasons (polar vortexes, etc). Though a more specific thesis is required for full support, the results aided the hypothesis and proved certain aspects of the prediction.

Error Analysis:

Throughout the course of the research and investigation, possible sources of error may have sprouted and thus altered the final decision or influenced it in certain aspects. For example, the utilization of satellites, though mostly accurate, have often been found to collect incorrect or biased data, thus possibly causing great impacts to the plotted trend lines observed.

Additionally, another source of error may be as a result of a misinterpretation of a scientific journal, further swaying the approach to the research and possibly the outcome. However, though these sources of errors exist, most have been mitigated as a result of a diverse array of data, thus preventing a specific source from swaying the final outcome profoundly. In regards to the misinterpretation of scientific journals, the literature review of several articles that offered similar clear explanations prevented from relying on a single paper that may have been biased, thus preventing any errors from entering the results and thesis.

Conclusion

Through intense data analysis and interpretation by utilizing plots, scientific journals, and custom artificial intelligence models, it is evident that the trends identified indicate a possible profound correlation between rising global temperatures and effects on the Arctic, thus leading to increased extreme climatic/weather events. With temperature differences (gradient)

decreasing between the polar regions and the tropics, anomalies within the jet stream occur, possibly forming more “wavy” jets streams that enable storms to do more destruction and cause cold Arctic air to reach past its normal/predicted borders. Furthermore, the data also suggests that the Arctic’s weather and Northeastern United States region’s weather correspond greatly, for when Arctic temperatures are high, the Northeast gains extremely cold temperatures.

Additionally, other weather events were found to be created and intensified as a result of climate change and temperature anomalies, such as the intensification of hurricanes and the creation of floods(which further ties back to decreasing ice mass within both polar regions).

These conclusions and results illustrate the grave danger Earth currently is in, with more frequent extreme weather events occurring every year, leading to ecosystems destroyed and lives lost for preventable issues. With climate change penetrating daily life, causing land and houses to be lost to sweeping waves, and hurricanes to destroy entire states and cities, it is important and vital to advance scientific knowledge and research within this domain. The identification of connections that are foundational to this global crisis will permit a greater comprehension of activities that may contribute to global warming as well as Arctic disturbances, allowing the possible prevention of those activities to save the current state of the environment.

Future Research:

Further studies into the molecular layer of Arctic disturbances, such as the thermal influenced intermolecular forces that may affect the boundaries of the jetstream, as well as stratospheric components that regulate the polar vortex, will be attempted to be pursued to advance the specificity of the research and discover new anomalies and phenomena that may be core to the mass-scale impacts. Additionally, research into the Gulf Stream may be optimal to explain warming effects on the Arctic, for warm Atlantic water is carried near the Arctic region, possibly causing a detrimental effect as Atlantic water grows increasingly warm.

Method Improvement:

Improvements in methods that could be made to advance and further support the conclusion found would be to gather an increased amount of data and obtain software capable of processing and graphing all of the data, which posed a challenge to the existing software possessed. An additional method that may improve the quality of the research was to collaborate with others, which unfortunately could not occur as a result of the increasing COVID-19 pandemic.

Mentor Impact:

Through researching at the Institute for Earth Observations, my project mentor greatly impacted the investigations being done through explaining various climatic effects and supplying access to a laboratory that enabled a greater quality of research and environment. The visualization tools provided by the lab, as well as the equipment needed to process vast databases and artificial intelligence models further incentivized the progression of the research being done, enabling greater time for scientific discussion and analysis with my project mentor.

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