RAINSTORMS AND REFUGEES:
CLIMATE CHANGE-RELATED FLOODING OUTCOMES FOR VULNERABLE COMMUNITIES OF NORTH CAROLINA.

by

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ABSTRACT

ZED BATES-NORRIS. Rainstorms and Refugees:
Climate Change-Related Flooding Outcomes for Vulnerable Communities of North Carolina. (Under the direction of DR. JACOB SCHEFF)

When we acknowledge environmental and racial violence in history and understand how communities of racial minorities have been disadvantaged, and when we fully understand the threat of the catastrophic effects of climate change to be entangled with the fate of the vulnerable, our resources compel us, as a society and as scholars, to mitigate the profound suffering and potential displacement caused by fossil fuels. We explore the consensus among predictive regional climate models and interpret the ways in which flood-causing severe storms would change before the next century; past (1981-2021) observations from FEMA already show great increases in flooding disasters in some socially vulnerable counties of NC. We place these storms within the context of historical environmental injustices and show how increased flooding risk could exacerbate the vulnerability of NC communities. Specifically, we concentrate on 9 NC counties that meet the criteria for the CDC Social Vulnerability Index and their susceptibility to heightened flooding due to heavy rainstorms, aiming to inspire targeted actions and policies that prioritize and protect the well-being of these folks.

Keywords: Climate change, flooding risk, inequality, vulnerability

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NC North Carolina

SVI Social Vulnerability Index

GIS Geographical Information System

IPCC Intergovernmental Panel on Climate Change

NCCSR North Carolina Climate Science Report

WMO World Meteorological Organization

PRISM Parameter-Elevation Regressions on Independent Slopes Model

CORDEX Coordinated Regional Climate Downscaling Experiment

RCP Representative Concentration Pathways

FEMA US Federal Emergency Management Agency

NCAR National Center for Atmospheric Research

MPI-ESM-LR Max Planck Institute Earth System Model

CanESM2 Canada Earth System Model second gen.

GFDL-ESM2M Geophysical Fluid Dynamics Laboratory Earth Systems Models

THESIS INTRODUCTION

BECOMING A REFUGEE BECAUSE OF SEVERE FLOODING IS A RISK WITH RISING PROBABILITY.

Can you imagine the fear and panic that rising rushing water causes? Can you imagine a scenario where "the only reason that you're alive is that you were lucky and strong enough to hold on while you watched your family die"? (*Dawson, 2006*). On average 21.5 million people a year since 2008 have direct experience with that kind of scenario according to the UN High Commission for Refugees (*2016*).

In 2020 alone 30 million people were displaced by disasters with 98 percent of the disasters being weather-based (*Norwegian Refugee Council, 2021*) and the Institute of Economics and Peace suggests that by 2050 a quarter of the people on Earth will become migrant from their homes due to "ecological threats" (*2020*). These statements are simplistic according to de Hass when the real issue is people's vulnerability (*The Migration Policy Institute, 2022*). For example the vulnerability to the socio-economic conditions and political ambitions that undermine the right to environmental self-determination and freedom from ecological destruction (*United Nations Convention Declaration on Human Rights 1948*). Internal displacement, migration, refugee-ness are probable but that is only one facet of climate change.

SEVERE FLOODING IS CONNECTED TO CLIMATE CHANGE CLIMATE.

change can increase the severity of storms and by extension the severity of ecological threats to NC communities. Flood disasters are one impact of climate change. They are already happening and will shape the conditions of communities in the state going forward. Florence, a hurricane that dropped 9 trillion gallons of precipitation in 2018 (*The*

Washington Post, 2018) and raised rivers to more than twice their flood stage, also displaced at least 656 NC households (*FEMA, 2020*).

Flood events that were considered "once-in-a-lifetime" now happen multiple times a decade (*NC State, 2020*) and those increases can be attributed to climate change (*Smiley et al, 2022*).

In the last 40 years, there have been more years with disaster declarations for hurricanes, severe storms, and flooding than at any other time in NC's history (*Disaster Declarations for States and Counties | FEMA.Gov, 2022, Past Disasters | NC DPS, 2022*). The high risk of flooding could heighten human suffering in the socially vulnerable communities in the state.

SEVERE FLOODING RISK, CLIMATE CHANGE, AND VULNERABILITY HAVE A RACIAL ASPECT IN NC.

Effectively addressing social vulnerability decreases human suffering (*Flanagan et al., 2011*). Perhaps suffering has not decreased because institutions and the research they produce has taught thinkers how to examine racial outcomes without an

understanding of how vulnerability (seen as problematic; a classification based on race, class, gender, ability) and the creation of social difference (race, class, gender, ability) happen at the same time (*Pulido, 2017*). Connections between social inequity, climate change, and flooding risk are not apparent (*Smiley et al., 2022*), though connections between race and floods such as mass displacement are presented with a high confidence level (*Institute of Economics and Peace, 2020; The United Nations, 2016*).

The structure of racism and racist violence has been obscured because of the one-dimensional focus on the intent of the "perpetrators" of racial violence (*Blee, 2005; Archer, 2020*) and the failure to situate the consequences of that violence in public memory. Blee tells us that the perpetrators are white mobs, white supremacist skinheads, racist doctors, and others. US laws place the burden of proof and legal enforcement on the vulnerable because the laws have been historically unable to question the "naturalness" of racial disparities (*Archer, 2020*) and racial violence.

Historians and scholars of racist violence like a 2020 statement by the American Historical Review (*2021*), Ida B. Wells Barnett (*1893*), Ibram X. Kendi (*2017, 2018, 2021*), Dr. Kimberly Crenshaw (*1991, 2012*), Nell Irvine-Painter (*1991*) and Derrick Bell (*1976, 1990, 1993*) agree that unemployment or under-employment (poverty), mass incarceration, displacement and housing segregation and even architecture and infrastructure (*Archer, 2020*) have been employed with the purpose of "striking terror" in racially ethnic environments.

Bell presents racism as an "integral, permanent and indestructible component of society" which allows racist violence, and even vulnerability, to be tinted with legitimacy and inevitability.

People's socio-economic status as a function of vulnerability is treated as the outcome of poor individual choices (*Archer, 2020*), that status being a consequence of a system obsessed with social difference. Kind of like climate change being treated as an individual responsibility instead of a consequence of the system created for us to live our lives reliant on fossil fuels.

Vulnerability to flooding risk could be seen as the material fruition of racialized norms about the environment (*Archer, 2020*).

Twentynine counties in NC are socially vulnerable based on the Centers for Disease Control and Prevention/Agency for Toxic Substances and Disease Registry Social Vulnerability Index (*2023; NCPDS, 2018*). The index, an examination of racial outcomes, is less useful when it promotes race, gender, and class as if intrinsic individual traits, instead of implicating manufactured social difference in NC. For example, cities that are racially segregated by highways such as Hayti and Charlotte, where road expansion severed communities from each other and bled out the resources and services that would have been buffers to vulnerability.

Road building is just one way that NC has created spatial and economic conditions that made people vulnerable in the first place. People in Charlotte still tell painful stories about being completely cut off by I-77 from friends and family, churches and schools that had been "down the street" (*CleanAIRE NC, 2023*). Perhaps proximity to a highway should be included in the SVI calculations since they have been shown to be tools of segregationist agendas contributing to persistent barriers (*Archer, 2020*).

Segregation through land use exerts enduring effects on a community's vulnerability because bridges, highways, and straightened waterways cannot be removed as easily as a "White's Only" sign. Unlike the tangible removal of discriminatory signs, these structures persist as enduring symbols of racist and environmental violence,

and, intertwined with the potential impacts of climate change such as heightened risks of severe flooding, compound negative racial outcomes. In environments designed to disadvantage non-white individuals, the challenges posed by climate-related hazards become even more formidable.

Studying the racial outcomes of racist policy can prompt the invention of things like the SVI to bring "awareness" and address individual needs, in a way that does not overly challenge the system or bring about good-faith solutions (*Pellow, 2007*). Since other well-respected vulnerability indexes like The Vulnerability Index-Service Prioritization Decision Assistance Tool that assesses the need for services for homeless people have already started to be phased out of use in NC, it could imply the SVI's ideology is suspect (*Brown 2018; Salim, 2020*).

The basic ideology of vulnerability indexes comes into question because assessments of them indicate that social differences are recreated and modes of resource allocation that favor whites persist (*Brown 2018; Salim, 2020*). This scrutiny reveals a broader societal blind spot, where the connections between social inequity, climate change, and flooding risk remain overlooked (*Smiley et al., 2022*) and should be studied.

In this study I developed approaches to confront the foundations of vulnerability ideology, as it relates to climate change, and to assess flooding risk for racial minorities in NC flood hazard zones. Based on the SVI's criteria of race and socioeconomic status, I assessed the ways social inequity and social difference are created in NC. I designed a spatial analysis of flood hazard zones which estimated the population and demographic character, leading to inferences about the impact of flooding risk on racial minorities.

I pursued answers about the frequency of severe rainstorms in a worst-case scenario climate by manipulating and comparing intervals of past precipitation to the data in models of future precipitation I applied this approach to nine socially vulnerable counties in NC, along with an assessment of racial and environmental histories and narratives that support a more critical view of vulnerability.

The approach allowed me to connect drivers of climate change, to divers of inequity, to drivers of environmental concerns related to flooding risk.

OBJECTIVES

I had 5 objectives for this project.

I wanted to analyze past data to understand how the number of severe rain events has changed since the eighties, and future simulations to understand projected changes in the frequency of severe rain events if the earth warms more than 2 degrees Celsius before the next century.

I sought to analyze the impact of the trends on the vulnerable minority communities in NC's flood zones, to depict the why of minority races in and around floodplains in NC, and to illuminate connections between social inequality and increased risk of flooding due to historical racist violence such as red-lining (*Ueland and Warf, 2006; Grundy, 2020*), environmental contamination (*Ladd & Edward, 2002; Driver, 2023*), and urban renewal (*Grundy, 2020*). Overall, the objectives were met and this study may advance the understanding of flooding risk, vulnerability, and climate change.

LITERATURE REVIEW

CLIMATE CHANGE'S EFFECT ON FLOODING.

In 1968 the Robinson Report, authored by Stanford scientists, connected fossil fuels to the rising levels of C02 and thus to the possibly devastating effects of a warmer climate, or "serious worldwide environmental changes" (*Robinson, Robbins, American Petroleum Institute, 1968*). That report was followed by many others and more evidence (*Franta, 2021; Supran et al., 2023*) confirming decades ago what we know from experience in the present. Despite that, and with the lives of billions at stake, the oil and gas and energy industry, shrouded by academic institutions, convinced the world that there was no scientific consensus on climate change (*Franta, 2021; Supran et al., 2023; Van Den Hove et al., 2002; Raymond, 1996, 2000; Semuels, 2017*). Less than 15 years later early signs of extreme climate change could be documented (*Hickman, 2017; Free Mantle Media, 1980*).

WARMING AFFECTS PRECIPITATION EXTREMES.

Climate change is a global phenomenon caused by the way we use fossil fuels. The volatile compounds help increase the C02 in the atmosphere and prevent heat from escaping into space. The extra heat interacts with systems like the water cycle, increasing rain in some places, and causing floods. The land (*Alexander et al., 2006*), oceans (*Cheng et al., 2019*), and air (*Jones et al., 1999*) have become warmer, which increases the melting of our glaciers and ice sheets.

Global surface temperature shares a linear dependency with the magnitude of climate extremes, and scales with regional temperature increases (*Seneviratne et al., 2016*). Hotter daily temperatures are happening more frequently, record-breaking hot days are more common since 1979 (*CNN*), and the meltwater from polar and arctic regions is rising sea levels for the 3 billion who live near coasts.

Overall there is more moisture available to evaporate into the atmosphere.

The Intergovernmental Panel on Climate Change report (*2021*) indicates that the rate of heavy rain will increase with the increase in maximum atmospheric moisture. Increases of about 7% more rain per degree Celsius. Understanding how that 7% may manifest regionally works best at daily resolutions since most of the extreme precipitation occurs within a day (*Barbero et al., 2017*).

Globally the amount of rain (*Contractor et. al, 2020*) falling in one day has increased since the middle of the 20th century (*Dunn et al. 2020*), and at the regional level, the NC Institute for Climate Studies Climate Science Report (*2020*) suggests that with more climate warming there could be at least a 6% increase in total annual precipitation. Kunkel et al. (*2020*) found that US region extreme 1-day events increased at a rate of 8% per decade, and that the southeast region's warm weather trends have been 20% wetter since 1949. A wetter region increases the risk of flooding, and that risk affects vulnerable people in rural and urbanized NC.

EXTREME RAIN WILL AFFECT URBAN AREAS, AND NC FLOOD ZONE RESIDENTS.

In 1965 Bookchin warned of the negative consequences of urbanization (*Herber & Bookchin, 1965*), and consequences continue to be revealed. River overflow and storm surge are most common in NC, and flash flooding due to activities like soil compaction and installing impervious roads contribute to the poor situation in urban areas. Counties like Mecklenburg and Wake (*NC Health News, 2023*) have lost thousands of acres of trees to development, destroying wetlands and other natural flood buffers.

Mind you, many of NC's urban rivers already suffer from colonial straightening treatments, or urban stream syndrome (*North Carolina Department of Environment and Natural Resources, 2013; North Carolina Emergency Management & North Carolina Department of Transportation, 2018*), and are ill-equipped to manage the increase in runoff and rainfall. Rural residents also experience river flooding, sometimes plagued by easily flooded lowlands, and are exposed to untreated agricultural waste (*Ladd and Edward, 2002*) when it runs off of over-saturated fields. Flooding is the biggest threat to housing, buildings, and support systems in the state (*NCDEQ, 2020*), and it could be argued it's also a threat to NC emergency management systems. NC has 100 counties and a spectrum of emergency amenities to match.

Differences in the levels of care, expertise, space, and price for those amenities contribute to poor outcomes for the vulnerable (*Hoover, 2020*) in urban and rural settings. NC has recently been more vocal about mitigation programs to address community emergency needs, without also exploring the systemic inequalities that undermine community resilience such as inequitable distribution of program funds, agents, or advertising.

SOCIAL INEQUITIES THAT CONTRIBUTE TO THE DISPROPORTIONATE EXPOSURE TO HAZARDS.

The language that people use to discuss the burden of climate change largely invokes race. That language seems too passive, it focuses on racial outcomes and refuses to take into account how racial violence and environmental violence are produced (*Pulido, 2017*), or the social inequities that stem from racialization (*Ueland and Warf, 2006*).

INEQUITIES RELATED TO THE ENVIRONMENT AND RACE IN NC**.**

For minority populations in NC there has been a historical struggle to redress the environmental violence that has been unequally targeted in their communities, like dense farming and hog waste lagoons that overflow in heavy rain (*Kurtz, 2022; Ladd and Edward, 2002*). Indigenous people in the state have been stewarding the land and have been unapologetically resisting social inequities in their environments, like unequal access and protection for clean water because of polluting pellet factories (*Southern Environmental Law Center, 2021*).

In 2023 a Lumbee scientist had to challenge revisionism of Lumbee history by an NC politician (*Boraks, 2023*) because indigenous people still have to fight for social equity, their sovereignty and the right to environmental determination. Black and indigenous people in particular have been burdened by agricultural waste and toxic and unregulated dumping, and segregationist infrastructure in NC (*Kurtz, 2022; Ladd and Edward, 2002; Grundy, 2020*). The Warren County landfill where the state planned to dump untreated toxic and carcinogenic waste, was not the first sight of unmitigated environmental violence in the US, yet it was the first site where the people created a movement, a practice of resistance and political change that drew the attention of the entire nation.

The US's environmental justice movement started in NC in Black communities where people care very much about their homes and health. Black and Indigenous people in NC, like others, have a connection to the land and a way of placemaking which is now recognized as more environmentally friendly than the traditional European stewardship model. "Great White Wilderness" narratives persist, overlooking sacred knowledge, because their connections are hard concepts for the dominant society to conceptualize, it would seem (*Finney, 2014*).

Weaponized incompetence like misunderstanding people because of their race or ethnicity makes resilience efforts harder (*Grace-McCaskey et al., 2021*). In Edgecombe County, after Hurricane Floyd in 1999, efforts to buy out flooded property were not settled quickly because residents wanted to maintain the founding history and the space for Blackness (*Grace-McCaskey et al., 2021*).

The mechanisms of Black placemaking are not considered valuable, aren't overtly understood by the dominant narrative, and when another 100-year flood came to Princeville 17 years later residents and infrastructure were even less resilient in buffering their community (*Grace-McCaskey et al., 2021*).

Neglecting minority neighborhoods and racial segregation are tactics of racial violence in NC whose impacts on equity become apparent in the correlation between floodplains and race (*Ueland and Warf, 2006*). Minorities are targeted and segregated into lowlands and floodplains then surrounded with suppressed wages, fewer services, and low socioeconomic mobility.

This neglect also manifests in a lack of shelters, early-warning systems, and evacuation routes. The systemic undermining of minority resilience increases the risk of climate refugee-ness, a state of being characterized by disproportionate impacts of climate change such as displacement, trauma, and homelessness (*United Nations High Commissioner for Refugees, 2016*). Research from authors like Ueland and Warf, NIH and Smiley et al. implore us to improve assessment tools and mitigate the human impacts, instead of focusing on mitigating damage to property.

Considerable effort has been put into understanding flood risk in NC for flood insurance assessments using GIS and radar, and recent investments into river gauges are intended to mitigate flooding on roads. The use of geographic information systems (GIS) has revolutionized the way we study and understand spatial phenomena like risk and climate change.

The majority of new studies that produce future flood projections based on hydrological models do not typically consider aspects that are also important to actual flood severity or damages, such as social vulnerability (*Sauer et al., 2023, Hinojos et al., 2023*), flood prevention measures (*Neumann et al., 2015; Şen, 2018*), flood control policies (*Barraqué, 2017*), and future changes in land cover. The quality and distribution of hazard mitigation amenities has been systematically under-researched and it reflects directly onto the minorities living in the flood hazard zones, exposing them disproportionately to hazards.

NC is no exception to the impacts of climate change, where the increased frequency and severity of floods have resulted in property damage and loss of life (*Samenow, 2018*). However, all communities are not equally affected by flooding, and understanding the demographics of the flood-prone areas can help.

RACIAL INJUSTICE IN NC.

NC's history is a tale of racializing all areas of society. From agriculture to zoos, NC cannot escape how it has racialized space and spatialized race. The segregation practices and racial violence of the Jim Crow era encoded a racist mode of conduct that abuses minorities. Natural disasters and climate change magnify the lasting impacts of these legacies. Urban renewal destroyed well-maintained abodes after conflating the state of the urban streams with the proximity to Black bodies in Mecklenburg County (*Grundy, 2020*).

Amid a housing crisis, worsened by patterns of gentrification post-urban renewal programs, even the housing market contributes to displacing minorities into environmentally unjust areas. In particular, Black and Hispanic individuals, are more likely to live in low-lying flood-prone areas than their white counterparts because "housing markets, particularly in the South, tend to segregate minorities in low-lying, flood-prone, and amenity-poor segments of urban areas" (*Ueland and Warf, 2006*). While there are too many instances of racial injustice to count, there are also instructional moments of confronting racial and environmental injustice and upholding humanity.

Protests in Warren County are well-known marker moments in the creation or "birth" of the nation's environmental justice movement because racial and economic minorities fought against untreated toxic waste being dumped in their local landfill. A landfill that I visited and it's literally in people's backyard; not two miles from the church where direct actions against the landfill were planned.

According to residents and activists from the town, Warren County wouldn't have been a suitable site, except for the existence of the mostly Black community, who legislators did not think would fight it. Industrial farming operations that produce billions of gallons and hundreds of thousands of tons of waste (*Southern Environmental Law Center, 2021; Hendrick, 2023*) are situated in eastern counties like Cumberland and Craven, in the neighborhoods of the descendants of enslaved people. Those people, the "contract poor", fight against exploitation from big agriculture and business-friendly, environmentally unjust policies (*Driver, 2023*). In this way, the plantation model and racial injustices are reproduced (*Purifoy, 2022*).

The plantation isn't the only big P haunting NC residents. Poverty continues to be one of NC's greatest contributions to the United States. People born poor in Mecklenburg County have nearly no chance of social or economic mobility (*Semuels, 2017*), where the median income for Black people is nearly the same as the poorest county in the state, but the fair market price for a 2-bedroom apartment in the city is 60% more expensive than that income. Poor, non-white, vulnerable people cannot find socioeconomic mobility now, they drown in tides of calamity now (*Nichol, 2011*). What chance is there to rebuild a life after being displaced in a flooding disaster?

METHODOLOGY

STUDY AREA

STATE

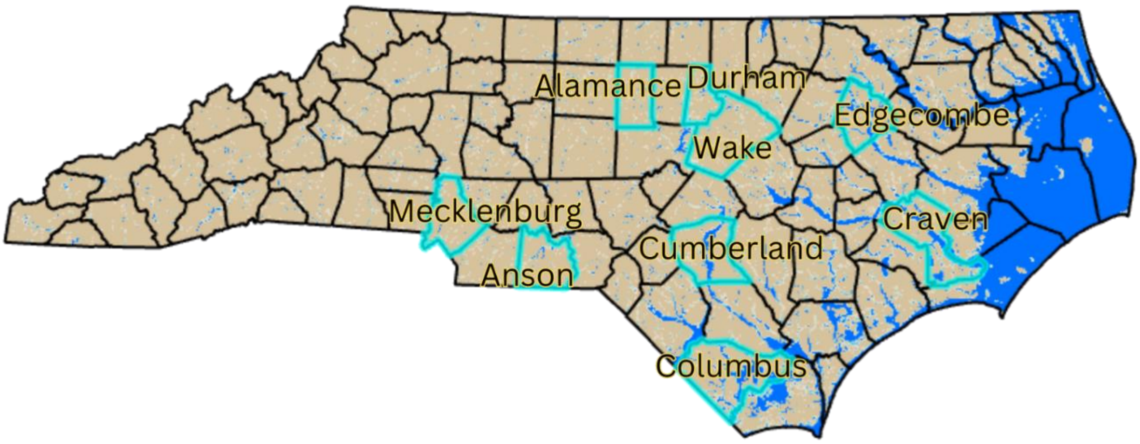
NC occupies space at about 35 degrees north and 79 degrees west in the northern hemisphere and it's considered a southern state in the US. 78 of the 100 counties in the state are considered rural and the rural populations are more likely to be considered vulnerable (*Gnomes, 2021*). I studied 5 counties that appear on the 2018 NC Social Vulnerability Map (*NC DPS, 2022*) and Alamance, Durham Mecklenburg, and Wake counties that have larger minority populations and a history of Black placemaking.

There are 17 designated river basins in the state and the North Carolina Sound is in one of the three major watersheds in the US (*Association of National Estuary Programs, 2023*). Annual rainfall is between 40 and 50 inches (*Kunkel, 2022*) supporting over 6 million acres of floodplains and wetlands (*North Carolina National Heritage Program, 2023*). There is not a single county in NC untouched by flooding losses (*Lattimore et al., 2019*). People in Wake, Mecklenburg, Durham, and Edgecombe have experienced problematic flooding, in some cases enough to make national news cycles for weeks.

NC has counties with over 3000 miles of rivers, streams, and creeks (*City of Charlotte, 2023*), which makes mapping the flood risk zones throughout the state a priority. FEMA is responsible for mapping the nation's flood zones and the North Carolina Floodplain Mapping Program (*2023*) was created to work with FEMA. With GIS tools, and accessible remote sensed topography data NC created geodatabases and feature layers that are adequate for scientific research.

Figure 1.

North Carolina study sites.



Note: An image of the state of North Carolina with county bounds outlined in black, and county names in black text with a yellow outline. The sites of study are outlined by a neon blue line.

COUNTIES

Alamance County has 173,877 residents (*United States Census Bureau, 2020*) and is not on the CDC SVI list (*US Centers for Disease Control and Prevention, 2022*). It has a large population of Black people because of the density of old plantations in the county and the normalization of anti-black ideology (*Russell, 2021; Albright, 2023*), like many places in NC. Approximately thirty percent of the county's population is minority (2020 estimate); of that fraction, twenty percent is Black people. Flood events severe enough to cause power outages have been recorded in the county (*Pattman, 2022*).

Anson County has a small population of 24,430 residents and received a 0.94 out of one for the SVI. The population is almost evenly split with 2020 estimates of 49.9 percent being Black people (*United States Census Bureau, 2020*). Anson has dealt with flash flooding as recently as June 2023 (*Gamertsfelder, 2023; Anderson et al., 2023*).

Columbus County has 55,659 residents and received a 0.94 out of one for the SVI, with approximately 36 percent of the population being Indigenous and Black people (*United States Census Bureau, 2020*). The extreme flooding in this county garnered national attention and Coast Guard involvement (*US Department of Commerce, 2023*).

Craven County has 100,674 residents and received a 0.80 out of one for the SVI. The minority population in Craven County is mostly Black people who make up approximately twenty-one percent of the total (*United States Census Bureau, 2020*). Craven County was impacted by Hurricane Matthew (*WNCT, 2017*).

Cumberland County has 333,508 residents and received a 0.86 out of one for the SVI. approximately thirty-seven percent of the county residents are Black people (*United States Census Bureau, 2020*).

Durham County has 326,126 residents and is not socially vulnerable (*United States Census Bureau, 2020*) however racist violence has been devastating here. One of the first and largest segregated centers of commerce was built by the residents of Hayti in Durham, which thanks to racial violence is now the site of Highway 147. 2020 estimates approximately forty-eight percent of the population are minorities, with Black people at thirty-four percent. Durham County government website indicates that the frequency of extreme flooding events is increasing in the county (*Durham County, 2023*).

Edgecombe County has 52,069 residents and received a 0.97 out of one for the SVI (*US Centers for Disease Control and Prevention, 2022*). In Edgecombe is Princeville, the oldest town chartered by Black people who represent approximately fifty-eight percent of the population in the county (*United States Census Bureau, 2020*). Its location is due entirely to it being “unwanted and flood-prone lands adjacent to the Tar River” (*McCaskey et al., 2021*).

Mecklenburg County has over a million residents and is not a socially vulnerable county. Black people represent approximately thirty-three percent of the people in the county (*United States Census Bureau, 2020*). Mecklenburg has approximately three thousand miles of waterways (*City of Charlotte, 2023*), some of which were straightened during colonial expansion, a process that, along with land use changes, contributes to flooding.

Wake County has more than one million residents and it is not a SVI county. Wake County's largest minority populations, ten percent, and twenty-one percent, are people who identify as Hispanic or Black (*United States Census Bureau, 2020*). Wake County still has neighborhood covenants that ban all races other than white (*WTVD, 2019*), while many minority neighborhoods are situated along the often-flooding Crabtree Creek (*Retana, 2022*).

DATA

The data I used for the demographic portion of the floodplain analysis came from NC state resources (*NC OneMap, 2023; NC DPS, 2023; North Carolina Flood Mapping Network, 2023; North Carolina Flood Mapping Program, 2023*), the US Census Bureau (*2020*) via an API key, and a flood risk zone map from the Flood Risk Information System (*2023*). FRIS has feature class layers accessible to the public.

Precipitation data is in the form of time series tables. Historical data are daily records of precipitation for the counties of interest from the last forty years and came from the Oregon State Parameter-Elevation Regressions on Independent Slopes Model, PRISM (*2022*). Those records model real-world measurements and have also been used by the NC government to assess rainfall (*North Carolina State University, 2024*)

Future daily precipitation projections for the North American region are credited to the Coordinated Regional Climate Downscaling Experiment, CORDEX (*Mearns et al., 2017*), and those projections are based on the RCP 8.5 scenario which predicts a temperature increase of 4.3 degrees Celsius by 2100 (*van Vuuren et al., 2011*). CORDEX is an online portal for the results of five regional climate models driven by nine global models.

HOW MANY FLOOD ZONES HAVE MINORITIES?

To test my hypothesis that there’s an overrepresentation of Black people and other racial minorities in flood-hazard-zones in NC I relied on the analyzing demographics within the flood-hazard-zone for each county. Flood hazard zones or footprints represent where water will go during a flood. Census tracts were represented by a feature class that I created by accessing an API key for the census data as well as Python libraries “Census” “US” and “States”. The initial tract information for NC was narrowed down to a county level using the

Pandas library, which allows for the manipulation of large data sets organized as time series and numerical tables.

I coded using the Pandas library, utilizing the data frame ability to group and summarize the data for a county. I grouped the data by the unique identifier GEOID, and prompted an output of the count of people in each demographic variable, in the study areas. The demographic variables I analyzed in this study were the detailed total population for non-Hispanic Whites(C02003_003E), Hispanics (B03002_012E), Native Hawaiians or Pacific Islanders (C02003_007E), Asians (C02003_006E), American Indians and Alaska Natives (C02003_005E), and Black people (C02003_004E).

I proceeded to use the flood-hazard-zone layer to create buffers that would help me narrow the census tract data to those zones. The code I wrote performed a one-millimeter planar buffer analysis on the flood-hazard-zone polygon layer without dissolves to preserve shape inside of the flood-hazard-zone polygons, followed by a spatial join between the buffer layer and the census tracts layer.

This method creates a situation where the tracts become intersected by the buffer in the flood-hazard-zones causing everyone in the county to be counted. Instead of relying on the raw number of people in the county, which would be better represented as a proportionality to the amount of buildings in the flood zone (*Titus, 2023*), I adjusted the population by thirty percent which is an amount of over-estimation for areal-weighting techniques (*Maantay & Maroko, 2009*). I explored the proportionality of the minority races in the flood-hazard-zones to the 2020 census numbers for the county by dividing the adjusted population by the 2020 county population for a traditional approach to displaying population representation. With Python's Matplotlib library, I generated histograms to help identify patterns and relationships visually. The Histograms were generated by counting the number of flood hazard zones and the people within the buffer. I used 10 class intervals for each race. The full code referenced here can be found in the GIS section of Appendix E: Python Script.

Figure 3.

Python script used to join a NC shapefile and NC census data.

```
In [8]: #join the dataframes so the tracts and the shape match.
        #use GEOID

        nc_df["GEOID"] = nc_df["state"] + nc_df["county"] + nc_df["tract"]

        # Join the attributes of meck tract and nc_df
        # Source: https://geopandas.org/docs/user_guide/mergingdata.html
        nc_merge = meck_tract.merge(nc_df, on = "GEOID")

        # Show result
        print(nc_merge.head(2))
        print('Shape: ', nc_merge.shape)
        # Save nc_merge to a shapefile in a folder
        #nc_merge.to_file(r'[illegible]nc_merge.shp')

  STATEFP COUNTYFP TRACTCE        GEOID NAME_x          NAMELSAD  MTFCC  \
0      37      119  002701  37119002701  27.01  Census Tract 27.01  G5020
1      37      119  005404  37119005404  54.04  Census Tract 54.04  G5020

  FUNCSTAT    ALAND  AWATER  ...  \
0        S  1671003       0  ...
1        S  5366655   53444  ...

                                         NAME_y  C02003_003E  B03002_012E  \
0  Census Tract 27.01, Mecklenburg County, North ...       2842.0         60.0
1  Census Tract 54.04, Mecklenburg County, North ...        870.0        865.0

  C02003_007E  C02003_006E  C02003_005E  C02003_004E  state  county   tract
0         0.0         40.0          0.0         62.0     37     119  002701
1         0.0        113.0          0.0       3102.0     37     119  005404

[2 rows x 23 columns]
Shape:  (305, 23)
```

Note: An image of 1 Jupyter cell with lines of script to join the census attributes to the NC shapefile. Attributes of the shape file are printed below the cell.

ANALYZE THE PAST FOR TRENDS IN DAILY SEVERE RAIN EVENTS.

Less than fifteen years after the Robinson report, early signs of extreme climate change hit NC (*FEMA, 2023*). This is the reason I chose to examine changes in precipitation amounts starting in 1980. A rainstorm is considered heavy if precipitation equals three or more inches (76.2 mm) in a day (*Kunkel et al, 2020*), and since daily records don't suffer as much truncation as hourly (*Barbero et al., 2017*). I used Python code to explore the records of days with three or more inches of rain.

I answered the question of how the frequency of heavy rainstorms has changed in the socially vulnerable areas of interest in NC, through analysis of daily precipitation amounts in a forty-year interval from 1981-2021 using the Explorer product from PRISM. I obtained high-resolution time series data for each county from the product. I used the Python library pandas to put the data in a data frame and resample it into a yearly frequency to prompt an output of the counts of heavy precipitation events for each year. After grouping the counts in twenty-year intervals. I used Matplotlib to plot the precipitation data for each county, then calculate and output the change in events over the last forty years. The full code referenced here can be found in the PRISM section of Appendix E: Python Script.

Figure 5.

Python script used for climate analysis (PRISM).

columbus

```
In [5]: col_precip=read_csv('H:\PRISM\precip_columbus.csv',index_col=0)
        col_precip = read_csv('H:\PRISM\precip_columbus.csv', parse_dates=['Date'], index_col='Date')
        # Resample the data to a yearly frequency
        yearly_data = col_precip.resample('Y').count()

        # Count the number of times that inchesPpt is >= 3 each year
        yearly_counts = (col_precip['inchesPpt'] >= 3).resample('Y').sum()

        # Group the yearly counts by 20-year intervals
        col_vicennial_counts = yearly_counts.groupby(pd.Grouper(freq='20Y')).sum()

In [6]: print(col_vicennial_counts)

        Date
        1981-12-31     2
        2001-12-31    14
        2021-12-31    22
        Freq: 20A-DEC, Name: inchesPpt, dtype: int64

In [7]: col_inc=((22-14)/14)*100
        print('The percent increase in heavy rain events in Columbus County is ' +str(col_inc))

        The percent increase in heavy rain events in Columbus County is 57.14285714285714
```

Note: An image of 3 Jupyter cells and the lines of script I wrote for Columbus County. The first cell shows the process for making the Columbus County precipitation time series .csv to a Pandas dataframe and the process of counting the volume records greater or equal to 76.2 mm/day. Subsequent cells show how the difference in event frequency for the past time interval was obtained from the first cell.

ANALYZE THE DEPENDENCE OF FLOOD STAGE ON RAIN AMOUNTS.

In an effort to understand river overflow, I investigated recurrence intervals of flood stages for rivers mentioned in disaster reports, which flooded towns in the areas of study. I obtained data for the study areas from the NOAA Precipitation Frequency Data Server (*2023*) and the USGS National Water Information System (*2023*). In this way, I was able to identify the type of flooding probability that would be induced during a 76.2 mm/day event. Determine how climate change will affect the frequency of severe rain events causing rivers to overflow.

I analyzed the future predictions for the change in the frequency of heavy rainstorms based on the RCP 8.5 scenario using CORDEX and Python. I evaluated projected changes in the frequency of heavy precipitation from storms by taking the difference of 76.2 mm/day events between the intervals 2021-2050 and 2051-2080. This comparison is to control for the difference in reality between the CORDEX models and the PRISM historical models. This means comparing projections with each other, instead of with the PRISM findings.

I retrieved thirteen NAM-22i grid models of raw daily precipitation projections, approximately a fifteen-mile resolution grid covering North America, from the Climate Data Gateway at NCAR (*Mearns et al., 2017*). The Python module Xarray allowed me to work with the large time series array that spanned 2006-2100. To obtain data that corresponded to the latitude and longitude of NC the precipitation data was sliced to the correct coordinates.

I created a variable to hold the entries that were greater than and equal to three inches of precipitation in a day. I split the entries by intervals of thirty years starting in 2021 and 2051 respectively and calculated the difference between the number of events between the first, and last time intervals. Matplotlib and Cartopy libraries were used to project the resulting data for each model onto a basemap of the region with a color bar to illustrate the range of change. Arrays generated from this analysis can be found in Appendix C: CORDEX Arrays. The full code referenced here can be found in the CORDEX section of Appendix E: Python Script.

Figure 7.

Python script used for climate analysis (CORDEX).

```
# get the difference btwn 2x30 yrs of nc prec events >=3

precipm1=model1['prec']
# Select the subset of data for North Carolina using latitude and longitude coordinates
nc_prec_m1 = precipm1.sel(lat=slice(33.8, 37.0), lon=slice(-84.7, -75.4))

#GE 3in events
ge_3_m1=(nc_prec_m1 >= 76.2)

# >=3 prec events for the first 30 years
nc_precip_first_30_m1 = ge_3_m1.sel(time=slice('2021-01-01', '2050-01-01')).sum(dim='time')

# >=3 prec events for the last 30 years
nc_precip_last_30_m1 = ge_3_m1.sel(time=slice('2051-01-01', '2080-01-01')).sum(dim='time')

# Calculate the difference in projected >=3 prec events for selected intervals
nc_precip_diff_m1= nc_precip_last_30_m1 - nc_precip_first_30_m1

# Print the results
#print('Difference in projected >=3 prec events: ', nc_precip_diff_m1)
```

An image of one Jupyter cell and the lines of script I wrote for CORDEX models. This figure illustrates the script written to assess the projected number of heavy rain events for the future time interval, and the difference between those intervals.

Figure 9.

Python script used for mapping climate analysis (CORDEX).

```
#make a map for the results

import cartopy.crs as ccrs
import matplotlib.pyplot as plt

def plot_dataset(dataset : xr.Dataset):
    # specify Coordinate Refference System for Map Projection
    projection = ccrs.Mercator()
    # Specify Coordinate Reference System wherethe data should be plotted
    crs = ccrs.PlateCarree()
    # create axes object with a specific projection
    plt.figure(figsize=(16,9), dpi=150)
    ax = plt.axes(projection=projection, frameon=True)
    # draw gridlines in degrees over Mercator map
    gl = ax.gridlines(crs=crs, draw_labels=True,
                      linewidth=.6, color='gray', alpha=0.5, linestyle='-.')
    gl.xlabel_style = {"size" : 7}
    gl.ylabel_style = {"size" : 7}
    # plot borders and coastlines with cartopy features
    import cartopy.feature as cf
    ax.add_feature(cf.COASTLINE.with_scale("50m"), lw=0.5)
    ax.add_feature(cf.BORDERS.with_scale("50m"), lw=0.3)
    ax.add_feature(cf.STATES.with_scale("50m"), lw=0.3)

    #specify extent of the map in minimum/maximum longitude/latitude
    lon_min = -75
    lon_max = -90
    lat_min = 33
    lat_max = 40
    #bring in the data
    cbar_kwargs = {'orientation':'horizontal', 'shrink':0.6, "pad" : .05, 'aspect':40, 'label':'Difference in projected >=3 prec
    nc_precip_diff_m7.plot.contourf(ax=ax, transform=ccrs.PlateCarree(), cbar_kwargs=cbar_kwargs, levels=21)


    ax.set_extent([lon_min, lon_max, lat_min, lat_max], crs=crs)
    plt.title(f"Model rcp85.MPI-ESM-LR.WRF")
    plt.show()


plot_dataset(nc_precip_diff_m7)
```

Note: An image of one Jupyter cell and the lines of script I wrote to visualize the difference in the number of events between the two near future intervals using Cartopy.

RESULTS

RESULTS OF THE CENSUS ANALYSIS AND GIS.

Traditional demographic analysis: Black people in the flood-hazard zones represent sixty-seven percent of their total population in a county, on average, after population adjustment. Hispanics in the flood-hazard-zones represent sixty-six percent of their total population in a county, on average, after population adjustment Asians in the flood-hazard-zones represent forty-nine percent of their total population in a county, on average, after population adjustment.

Indigenous people in the flood-hazard zones represent twenty percent of their total population in a county, on average, after population adjustment. Pacific Island and Hawai'i people in the flood-hazard zones represent thirty-six percent of their total population in a county, on average, after population adjustment. The white people in the flood-hazard zones represent sixty-two percent of their total population in a county, on average, after population adjustment. These numbers represent individuals of a single race and do not represent people who identify as multi-race.

There are no counties in the study area that have a Black population higher than sixty percent of the total. Similarly for each minority racial category, the people represent way more on average for their county in the flood hazard zones, than in reality. The white people's average is slightly lower compared to their percentages as a demographic in a county; for example in Wake Alamance and Cumberland white people represent more than seventy percent of people in the county.

Histogram analysis: Histogram analysis: Histograms were used to analyze the information within the buffers, and to understand the way that the data might be distributed in the flood hazard zones. A pattern seems to emerge that supports Uland and Warf, 2006. White people have populations in fewer low-lying, flood hazard zones than minorities.

The maximum number of flood zones for any given class-interval for white populations is less than the maximum for racial minorities except Black people, in some instances. A maximum count of flood hazard zones for a class interval of whites is nineteen on average. Thirty-three flood hazard zones for Black people, Asian people are counted in fifty-nine flood hazard zones on average, Hispanic people in forty-three flood hazard zones on average according to the buffers, Pacific Islanders and Indigenous people are counted in the most flood hazard zones, eighty-two and sixty-seven respectively, on average. Black and white people in the study areas have similar results in the number of counted flood hazard zones.

Figure 11.

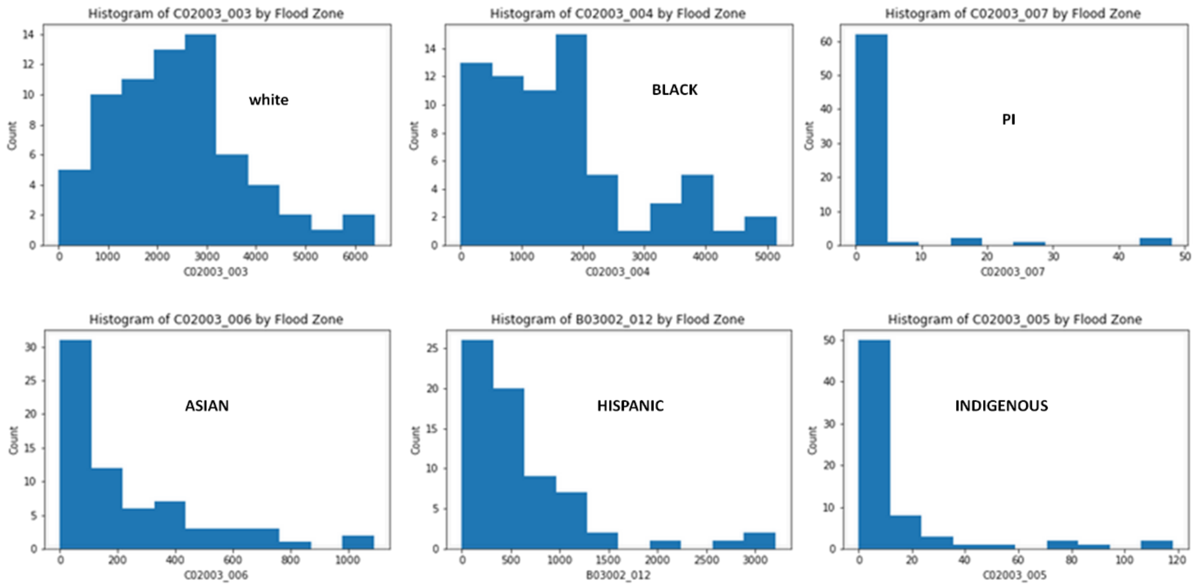
Study area demographics analysis, separated by county.

			Alamance		
		2020 Census County Population	2020 NCone Flood Hazard Zones Population	2020 Ncone Population adjust 0.30	Percent in Flood Hazard Zones
Asian		3814	2679	1875	49%
Black		37767	32917	23042	61%
Hispanic		24703	21153	14807	60%
Native		4693	688	482	10%
PI		248	54	38	15%
White		116227	114429	80100	69%
			Anson		
		2020 Census County Population	2020 NCone Flood Hazard Zones Population	2020 Ncone Population adjust 0.30	Percent in Flood Hazard Zones
Asian		390	315	221	57%
Black		12196	11990	8393	69%
Hispanic		1002	1002	701	70%
Native		308	108	76	25%
PI		14	14	10	70%
White		11784	11540	8078	69%
			Columbus		
		2020 Census County Population	2020 NCone Flood Hazard Zones Population	2020 Ncone Population adjust 0.30	Percent in Flood Hazard Zones
Asian		310	246	172	56%
Black		17330	16519	11563	67%
Hispanic		3061	3061	2143	70%
Native		2588	1964	1375	53%
PI		15	10	7	47%
White		35366	34770	24339	69%
			Craven		
		2020 Census County Population	2020 NCone Flood Hazard Zones Population	2020 Ncone Population adjust 0.30	Percent in Flood Hazard Zones
Asian		4192	2982	2087	50%
Black		22472	21899	15329	68%
Hispanic		7195	7644	5351	74%
Native		2435	673	471	19%
PI		309	144	101	33%
White		73112	71278	49895	68%
			Cumberland		
		2020 Census County Population	2020 NCone Flood Hazard Zones Population	2020 Ncone Population adjust 0.30	Percent in Flood Hazard Zones
Asian		14391	8452	5916	41%
Black		142387	124500	87150	61%
Hispanic		39498	40081	28057	71%
PI		2785	1210	847	30%
White		168889	162289	113602	67%
			Durham		
		2020 Census County Population	2020 NCone Flood Hazard Zones Population	2020 Ncone Population adjust 0.30	Percent in Flood Hazard Zones
Asian		20606	15802	11061	54%
Black		117964	112965	79076	67%
Hispanic		50104	43051	30136	60%
Native		7297	850	595	8%
PI		414	168	118	28%
White		159486	161588	113112	71%
			Edgecombe		
		2020 Census County Population	2020 NCone Flood Hazard Zones Population	2020 Ncone Population adjust 0.30	Percent in Flood Hazard Zones
Asian		207	84	59	28%
Black		28274	29920	20944	74%
Hispanic		2706	2512	1758	65%
Native		714	176	123	17%
PI		29	27	19	65%
White		19003	20497	14348	76%
			Mecklenburg		
		2020 Census County Population	2020 NCone Flood Hazard Zones Population	2020 Ncone Population adjust 0.30	Percent in Flood Hazard Zones
Asian		83012	66376	46463	56%
Black		335707	346514	242560	72%
Hispanic		169922	146710	102697	60%
Native		22135	3818	2673	12%
PI		1712	426	298	17%
White		596678	56313	39419	7%
			Wake		
		2020 Census County Population	2020 NCone Flood Hazard Zones Population	2020 Ncone Population adjust 0.30	Percent in Flood Hazard Zones
Asian		111979	80059	56041	50%
Black		230603	220232	154162	67%
Hispanic		128241	110961	77673	61%
Native		21770	3413	2389	11%
PI		1863	470	329	18%
White		740876	696626	487638	66%

For example, in Durham County Black and white people in census tracts containing approximately three thousand people live in approximately fourteen flood hazard zones. Other minority groups such as Hispanic and Indigenous people at approximately twenty-five and sixty flood hazard zones respectively, were individuals and groups. Compared to the majority, minorities in NC live in thirty-eight percent more flood hazard zones than their white counterparts. Histograms for each county are included in Appendix B: County Histograms.

Figure 13.

Durham County Histogram.



Note: The x-axis in this figure is the population of a race separated by 10 class-intervals, the y-axis is the count of flood hazard zones. This is an image with a white background, black text, and vertical blue bars.

RESULTS OF THE RIVER INCIDENCE ANALYSIS.

The probability of severe flooding like a one-hundred-year flood has recently been evaluated accounting for the effects of climate change, where Marsooli and Lin (*2019*) suggest recurrence be readjusted to reflect a lower threshold of one to thirty years (*Davis, 2023*).

Meaning floods of the same magnitude have and will recur more frequently by the end of the century, based on the worst warming pathway (*Marsooli et al., 2019*). NC is evaluating how much to adjust flood probabilities (*Moore, 2023*), and updating flood insurance maps to better reflect projected flooding (*Guilford County of North Carolina, 2023*)

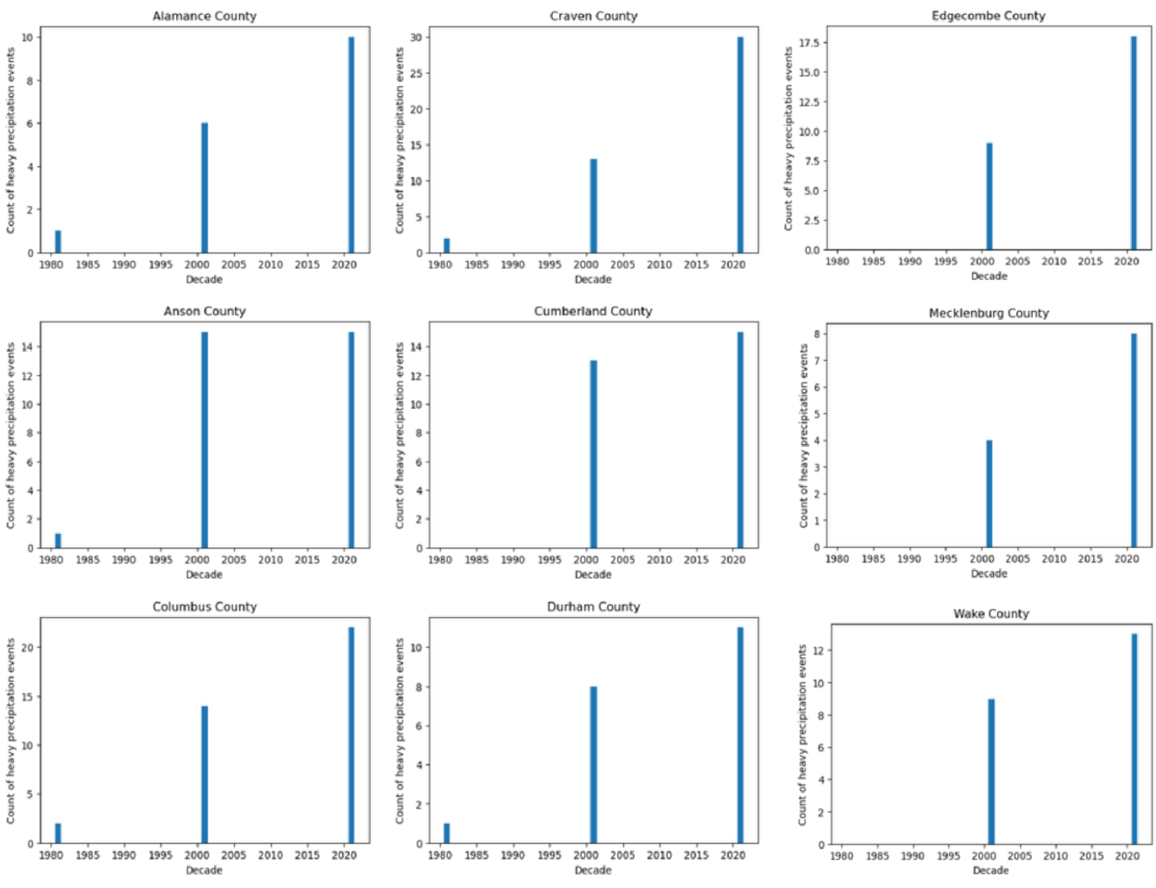
Anson, Craven, Durham, Mecklenburg, and Wake County rivers would reach one-year flood recurrence intervals at approximately 76 mm rain/day (*NOAA, 2023*). The Tar River which overflows into Edgecombe has a flood stage between five and twenty-three feet (*USGS, 2023*), exceeded five-hundred-year floods and raised nearly thirty feet above its flood stage during Hurricane Floyd, and more than twenty feet during Matthew (*NOAA, 2019; The Weather Channel, 2016*). The Tar River has reached flood stage since the beginning of its historical record and has not been found to have a statistically significant increasing trend in peak discharge (*NC Emergency Management, 2018*).

A twenty-five to fifty-year flood recurrence interval would be met at approximately 76 mm/day (NOAA, 2023). There are a variety of environmental concerns about the Tar River according to the NC Department of Environment and Natural Resources Division of Water Quality in 2014 (*North Carolina Emergency Management & North Carolina Department of Transportation, 2018*) which could contribute to secondary hazards like disease outbreaks. The Cape Fear River and The Neuse River impact the areas of study and have various stages along their routes. Both rivers overflowed their banks and flooded surrounding towns during Hurricane Florence. Because these rivers are so large, the recurrence interval is larger. For the Neuse, a five-year recurrence interval flood would be triggered by a severe rainfall event at the Neuse River near Raleigh (*NOAA, 2023*). The Raleigh station is close to the headwaters where the waterways can be narrower, and likely to be more impacted by heavy rain events than near its exit near New Bern NC.

Cape Fear River in Cumberland County, one of the furthest points from the headwaters, has a one-year recurrence interval at approximately 76 mm/day (*NOAA, 2023*). A one-year flood is like a typical inundation for a floodplain, and not generally considered bad, depending on the circumstances, in the absence of a more accurate representation of probability. Meaning that the chance of a type of flood gets higher the more of the type of flood happens.

Figure 14.

Precipitation difference bar graphs for each county (PRISM).



Note: An image of 9 bar graphs labeled by county. Number of events is on the y-axis, the time in decades is the x-axis. The bars represent the number of events between 1981-2001 and 2002-2021. Events before 1981 were not part of the analysis. This is an image with a white background, black text, and vertical blue bars.

RESULTS OF CLIMATE CHANGE ANALYSIS

PAST.

Analysis of the past precipitation trends, from 1981-2021 (excluding 1980), show increases in heavy rain events for all counties except Anson. Raw counts indicate a range for the increase in the number of events from zero to seventeen. Alamance County had a sixty-six percent increase in the number of severe events. Columbus' increase was fifty-seven percent, Cumberland fifteen percent, Durham was thirty-seven percent and Wake forty-four percent. Compared to Craven County with one hundred-thirty percent increase, and Edgecombe and Mecklenburg counties which had one hundred percent increase.

FUTURE.

The results of the analysis of the climate models show wide-ranging increases in events before the next century, based on RCP 8.5. The models also indicate that there could be fewer severely rainy days in some areas of the state like the western counties. The extremely negative values show low frequency change areas. All models referenced here are included in Appendix D: CORDEX Models.

Three models predict increases of more than twenty events in NC in the next sixty years. These models have a similar rate of change as the past forty years. For example, the rate of change was seventeen more events in forty years, and the models say it could be at least a change of twenty more events in the next sixty years. There is no indication if this change is linear, or if there will be days in the next five years with fifty severely rainy days for the vulnerable people in Craven, and years with only thirty-three.

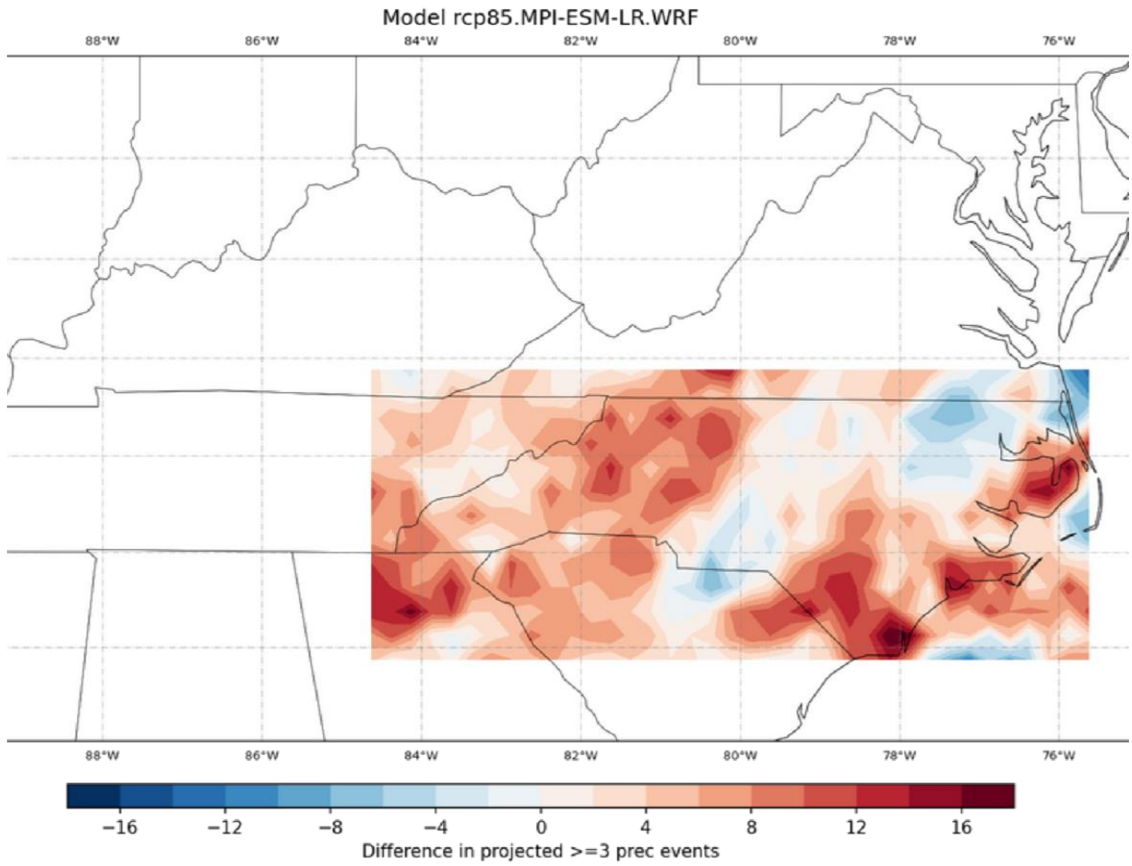
Though there is no real moderation in the worst-case climate scenario there are five models that can be considered in the middle range, predicting up to forty more events than there have been since 2021. Those models were driven by three global climate model drivers:

MPI-ESM-LR, CanESM2, and GFDL-ESM2M. Five models predict increases of more than forty. This would mean Craven County could have seventy severely rainy days before the middle of this century, for example. All CRCM5-UQAM models have agreement in moderate-strong increases in severe rain for the eastern part of the state affecting Edgecombe, Craven, Columbus, Durham, Wake and Cumberland. The Canadian models are driven by two global versions of the CRCM5-UQAM and the Max Planck Institute's global model.

There was no relationship between these last two groups of models and the kind of driver model. Models were inconsistent among drivers in negative values predictions. Three MPI-ESM-LR driven models indicate some agreement of less rainy events in the northwest of NC, but do not agree on the difference in events predicted in the central region. The mean change in precipitation for all models is positive. Average increases in severe rain events range from approximately three to thirteen more events if the worst global warming pathway becomes a reality.

Figure 16.

Projected difference in precipitation events. Model rcp85.MPI-ESM-LR.WRF (CORDEX).



Note: Images of future climate models with areas of blue, white, and red, overlaying a map I visualized using Cartopy. Models have a horizontal color bar at the bottom going from blue (left) to red (right) illustrating the change in events as a range from negative to positive.

DISCUSSION

DEPICT THE WHY OF MINORITY RACES IN AND AROUND FLOODPLAINS IN NC.

When applying GIS techniques in floodplain analysis researchers have focused on creating products like the insurance maps from FEMA which assess buildings, roads, businesses and other material losses to entities (Titus, 2023). The ability to assess ways people may be affected becomes convoluted at best when using the same methods. There is a fundamental misunderstanding of social difference (Pulido, 2017) that plays out in social surveys like the census which then requires interpolation of estimates, and proxies for proximity like number of buildings or block density (Titus, 2023)

If trying to understand how different demographic groups are affected by flooding, estimation becomes even more problematic. Necessarily people's private information must be protected when scraping data, but I found the categorical techniques and products that are currently popular to be stifling to the actual question of "what is the race of people in the flood hazard zones?". Some over- or underestimation is expected among the current GIS assessment methods, but the literature implies that flood zone factors impact the demographic percentages by less or greater than 0.30 (*Maantay & Maroko, 2009; Titus, 2023*).

This means that no clear answer can emerge without extensive controls, and the invention of weighting techniques that would include exacerbating factors like floodplain construction booms, rural or urban settings, or density sensitivity, and even finding a better way to represent people's spatial relationship to risk.

Additionally, there is a limit to identifying how close or far someone is to the flood hazard zone. A pattern seems to emerge from the histogram analysis that racial minorities are present in small numbers in more flood hazard zones than whites. Comparing class-intervals for example, whites seem to be in fewer flood hazard zones in the class interval 0-1000 in every county except Mecklenburg. This could imply that all SVI counties and many others with minorities should be focusing on mitigating the worst of the flooding risk for a smaller number of people and placing amenities within communities of minorities.

It's hard to assess the quality of the amenities in flood zones with remote techniques because there is less integration of this kind of data into GIS, there is mostly area information (*Maantay & Maroko, 2009*) that assists in characterizing material losses. Amenities like good river quality, hazard shelters, levees, and early warning systems are found to be linked with race and vulnerability (*Hoover, 2020*) so it can be implied that the flood hazard zones where the majority are white have amenities.

Exploring this could further illustrate how social difference is created, and provide opportunities for redressing vulnerability to flood risk and racial violence.

To refine and strengthen the racial aspects of flooding it would be good to cultivate a better understanding of the amenities that may be distributed based on race. That is to say, white people also live in flood zones, at slightly lower proportions than their average for a county, but it's harder to explore the resilience of those communities, versus resilience in flood zones that do not have white people (*Sauer et al., 2023, Hinojos et al., 2023; Neumann et al., 2015; Şen, 2018; Barraqué, 2017*).

Without more refining, the type of flood zone in terms of environmental degradation can be implied to be spatially connected to race. Researchers have to rely on historical narratives (*Grundy, 2020; Grace-McCaskey et al., 2021; Wells-Barnett, 1893*) and the preservation of public memory at places like the African American History Center in Alamance and the Hayti Heritage Center in Durham to depict the why since racial violence cannot currently be controlled for in the data.

Though it was hard to create the picture I desired using spatial tools, the literature (*Kurtz, 2022; Ladd and Edward, 2002; Ueland and Warf, 2006; Grace-McCaskey et al., 2021*), and demographic results of this project still indicate that on average minorities represent a greater percentage in the flood hazard zones (*Ueland and Warf, 2006; Grace-McCaskey et al., 2021; Smiley et al., 2022*) Black and Hispanic people are the largest minority groups in NC and do not represent more than sixty percent of any of the people in any of the counties studied.

Yet when looking at the flood hazard zones for example in Edgecombe approximately fifty-eight percent of that county is Black people, yet Black people represent seventy-four percent of the people estimated to be in the flood hazard zones. Hispanic people are similarly overrepresented in the flood hazard zones, compared to census estimates. The proportion of the number of the Black Indigenous and people of color in a county that live in a flood hazard zone is more than half of the total, on average. More than half of all the people in each racial group in a county are estimated to be in the flood hazard zone, based on areal weighting and an adjustment of thirty percent.

Intentionally, this survey brought to light the limitations of the current modes of assessing flood risk when it is people-focused. A thirty percent underestimation might be ok for business, but not for evacuation plans.

ANALYZE PAST MODELS TO TEST IF WARMING HAS AFFECTED THE NUMBER OF EVENTS

Without hesitation, the number of events has increased since 1981 for all but one county in my study area. The increases in rainy days as we approach the “point of no return” in atmospheric warming, on the heels of a contentious global climate change conference that barely condemned fossil fuels, while imperial entities ramp up the environmental degradation in the lungs of the world, the Democratic Republic of Congo, seem utterly preventable. The dependence on fossil fuels played out exactly like scientists proved it would (*Franta, 2021; Supran et al., 2023*).

The purported love for conservation is discordant with the literal machines of environmental destruction that prod us toward the precipice of annihilation. The results of this analysis are unsurprising. Research clearly relates atmospheric warming, and surface warming with increased precipitation. The yearly frequency of severely rainy days in the study areas has increased and could indicate a permanent shift in the climate thanks to warming, and could be a result of a short-term trend. A Short-term trend still implies 30-40 years, which is enough time to learn from hurricanes Matthew, Florence, and Katrina. The risk of another disaster declaration in NC due to flooding is more probable now than it was in 2000, even if it was a trend the worst of the suffering from flooding hazards in the next forty years could be alleviated by prepping like it's 2016.

Additionally, the recurrence interval, the metric for the probability of a type of flood, is not as adequate for predictions because of how flooding risk has changed (*Marsooli et al., 2019*). Rivers are more likely to flood at 76.2 mm/day than in the past and it might be tempting to shrug off forty 1-year type floods in a year, being critical and frequent in evaluating hazard assessments would take into account the compounding risk leading to five 100-year type floods in a year.

NC and partners like Appalachian State University have recognized the need to study the increased frequency of disasters (*Davis, 2023; Appalachian State University, 2019*). There's a wealth of research that confirms state and national-level reports. Yet the state still struggles to lessen the impacts in an organized effort (*UNC Chapel Hill, 2021*). There have been historic changes to resiliency such as in the coastal town of Nags Head (*Town of Nags Head,* *2023*) by developing a risk-based approach to their hazard mitigation plan that specifically addresses storm surge and I think that adopting similar hazard management resolutions is absolutely responsible behavior.

ANALYZE PREDICTIVE MODELS TO DETERMINE THE FREQUENCY TRENDS FOR FUTURE HEAVY RAIN EVENTS IF THE EARTH WARMS MORE THAN 2 DEGREES CELSIUS BEFORE THE NEXT CENTURY.

If the PRISM analysis can be supposed as a control, Anson saw no increase in frequency, Craven had seventeen more events, then the moderate amount of increase could be inferred to be less than twenty events over a similar time interval. If proportionality were taken into account, the models with thirty more events would be moderate. These predictions fall within Kunkel et al. observed increase in one-day severe events of eight percent per decade. On average the change in frequency is positive and greater than two events per year, for the next sixty years.

The models slightly differ from the predictions in the NCCSCS report (*2020*) which indicate the west could be wetter. The areas with the most increases in severe precipitation frequency seem to be east of Mecklenburg. Models are limited by their drivers and by the amount of information available to those drivers. The complicated data retrieval and storage systems can also influence the outcome by say someone working in a different country than the data of origin with limited access to the metadata or foundational theory of the tool.

Analyze the impact of the trends on the vulnerable minority communities in NC's flood zones.

To analyze the impact the future trends might have on minority communities I looked at the impact from past storms. More disaster declarations (*FEMA, 2022*), displacement internally and externally, and increasing vulnerability to the flooding risk since 1981. Vulnerability has increased in NC, particularly in the areas of study which were not vulnerable, places in Mecklenburg and Durham are seeing a creation of stark social differences thanks to gentrification.

It's not a stretch to imagine the same or worse social outcomes in the next sixty years. There is no model that can predict the trends in vulnerability to climate change, but I wish there were. If vulnerability increases with the frequency of severely rainy days vulnerable peoples' lives could get unimaginably worse.

CONCLUSION

ILLUMINATE CONNECTIONS BETWEEN SOCIAL INEQUALITY AND INCREASED RISK OF FLOODING DUE TO HISTORICAL RACIST VIOLENCE SUCH AS REDLINING, ENVIRONMENTAL CONTAMINATION, AND URBAN RENEWAL.

This thesis was partially written during the 2023 UN Climate Change Conference which was contentious to the last moment. Notably the global conference had thousands more big oil lobbyists than any previous conferences, and climate activists' calls for accountability from the largest polluters were suppressed, including a 12-year-old activist from India. Such discord between the people of the world and the interest of global industries raises questions about the relevance of the findings presented in this paper.

While the findings of this research have the potential to inform studies in geography and history by shedding light on the intersections between racial and environmental violence and flood risk, and by implying it’s time to dismantle segregationist agendas, prevailing societal trends suggest that dominant society is moving away from those kinds of values. It’s de rigueur for governments and corporations to engage in schemes that privatize humanitarian, environmental, agricultural, and conservation efforts in resource-rich nations turning them into industries “with the single goal of repaying the loans” to international financial institutions (*Pellow, 2007*). Governments and corporations increasingly prioritize profit-driven agendas over environmental and humanitarian concerns.

Amidst these challenges, the question arises: Is it worthwhile to engage in scholarly pursuits that confront entrenched power structures if the dominant narrative surrounding climate change and migration remains unchallenged? And if those institutions and individuals can exert enough control to push a narrative that maybe climate change shouldn’t be a priority? Government, corporations, NGO’s, academia, and this social structure that's built on racism wield immense power and seem disinclined to address systemic injustices or discriminatory practices.

If the entities that provoke our way of understanding ecological threats and human rights don't want to reevaluate their narrative and start blaming infrastructure, development projects, and imperial expansion this research seems like yelling into an abandoned mine. What governments do to mitigate "ecological threats" will play a big part in people's livelihoods (*The Migration Policy Institute, 2022*) whether a climate conference decides to address fossil fuels, or not. If communities do not have access to the mechanisms that relieve vulnerability and ensure their livelihoods, they are at a higher risk of being impacted by severely rainy days. If the frequency of severely rainy days continues to increase, vulnerable communities are exposed to risk more frequently and this leaves less time to absorb or process disruptions, leading to a hazard like flooding becoming disastrous environmentally and socially.

Moreover, the objectivity of hazard research is called into question when scientific negligence and complicity exacerbate human suffering. Of course, there are outspoken individuals like "Planet Walker" John Francis who refused gas-powered transportation for 22 years and was one of the first people to write academically on oil spills, Robert Bullard the father of environmental justice theory, and transnational activists like Licypriya Kangujamwho was silenced at COP 28. However, in the face of the results of this research like how cities are still segregated and still fighting pollution, the outspokenness at their little events, writing papers for academic echo chambers, and conforming to the idea that change needs governmental approval only serves the "treadmill of production, a concept for a self-reinforcing mechanism causing ecological and social harm (*Pellow, 2007*).

I did this project so that someone might have their eyes opened to the red threads connecting race, vulnerability, climate change, and disaster risk when they are creating products to address climate change like risk maps. I hope that by adding to the emerging science linking these things, there may form a process of alleviating human suffering methodologically and through multiple disciplines before the predicted results in this paper become a reality.

Researchers can stop parachute science, and instead focus on what decolonial futures look like. Geographers can begin to move away from xenophobia that drives over-population fears so that migration research in a warming world doesn't end up justifying the eco-fascist ideology that the planet would be better off without people. Ecologists and environmentalists can formulate challenges to the lucrative environmental credits system, which would help remove capital from the environmental justice process. Hazard managers and map makers can stop giving material loss the main stage, and instead talk about cultural losses. In conclusion, the connections between social inequity and increased risk of flooding are easily illuminated, but not easy to see if you don't have a right way of thinking which focuses on alleviating human suffering.

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APPENDIX A: DEMOGRAPHIC TABLES

A table of the study area demographics analysis, separated by county. This is an image of an excel spreadsheet with a white background and black text. The county names are highlighted in blue. The first column is census data, the second column is the data collected from the flood hazard zone buffer, the third column is an adjustment of the buffer population by thirty percent, and the last column is the percentage of each race in the flood hazard zone for each county.

			Alamance		
		2020 Census County Population	2020 NCone Flood Hazard Zones Population	2020 Ncone Population adjust 0.30	Percent in Flood Hazard Zones
Asian		3814	2679	1875	49%
Black		37767	32917	23042	61%
Hispanic		24703	21153	14807	60%
Native		4693	688	482	10%
PI		248	54	38	15%
White		116227	114429	80100	69%
			Anson		
		2020 Census County Population	2020 NCone Flood Hazard Zones Population	2020 Ncone Population adjust 0.30	Percent in Flood Hazard Zones
Asian		390	315	221	57%
Black		12196	11990	8393	69%
Hispanic		1002	1002	701	70%
Native		308	108	76	25%
PI		14	14	10	70%
White		11784	11540	8078	69%
			Columbus		
		2020 Census County Population	2020 NCone Flood Hazard Zones Population	2020 Ncone Population adjust 0.30	Percent in Flood Hazard Zones
Asian		310	246	172	56%
Black		17330	16519	11563	67%
Hispanic		3061	3061	2143	70%
Native		2588	1964	1375	53%
PI		15	10	7	47%
White		35366	34770	24339	69%
			Craven		
		2020 Census County Population	2020 NCone Flood Hazard Zones Population	2020 Ncone Population adjust 0.30	Percent in Flood Hazard Zones
Asian		4192	2982	2087	50%
Black		22472	21899	15329	68%
Hispanic		7195	7644	5351	74%
Native		2435	673	471	19%
PI		309	144	101	33%
White		73112	71278	49895	68%
			Cumberland		
		2020 Census County Population	2020 NCone Flood Hazard Zones Population	2020 Ncone Population adjust 0.30	Percent in Flood Hazard Zones
Asian		14391	8452	5916	41%
Black		142387	124500	87150	61%
Hispanic		39498	40081	28057	71%
Native		14413	4299	3009	21%
PI		2785	1210	847	30%
White		168889	162289	113602	67%
			Durham		
		2020 Census County Population	2020 NCone Flood Hazard Zones Population	2020 Ncone Population adjust 0.30	Percent in Flood Hazard Zones
Asian		20606	15802	11061	54%
Black		117964	112965	79076	67%
Hispanic		50104	43051	30136	60%
Native		7297	850	595	8%
PI		414	168	118	28%
White		159486	161588	113112	71%
			Edgecombe		
		2020 Census County Population	2020 NCone Flood Hazard Zones Population	2020 Ncone Population adjust 0.30	Percent in Flood Hazard Zones
Asian		207	84	59	28%
Black		28274	29920	20944	74%
Hispanic		2706	2512	1758	65%
Native		714	176	123	17%
PI		29	27	19	65%
White		19003	20497	14348	76%
			Mecklenburg		
		2020 Census County Population	2020 NCone Flood Hazard Zones Population	2020 Ncone Population adjust 0.30	Percent in Flood Hazard Zones
Asian		83012	66376	46463	56%
Black		335707	346514	242560	72%
Hispanic		169922	146710	102697	60%
Native		22135	3818	2673	12%
PI		1712	426	298	17%
White		596678	56313	39419	7%
			Wake		
		2020 Census County Population	2020 NCone Flood Hazard Zones Population	2020 Ncone Population adjust 0.30	Percent in Flood Hazard Zones
Asian		111979	80059	56041	50%
Black		230603	220232	154162	67%
Hispanic		128241	110961	77673	61%
Native		21770	3413	2389	11%
PI		1863	470	329	18%
White		740876	696626	487638	66%

APPENDIX A: DEMOGRAPHIC TABLES

I have provided an example of a csv file that was generated from the flood hazard zone buffer. This is Durham County. This is a black-and-white image of a spreadsheet. The column names are GEOID, NAMELSAD, C02003_003, B03002_012, C02003_007, C02003_006, C02003_005, C02003_004. This is meant to show how the data was organized in the dataframe before it was used to make the population table and the histograms.

GEOID	NAMELSAD	C02003_003	B03002_012	C02003_007	C02003_006	C02003_005	C02003_004
37063001002	Census Tract 10.02	2261	2911	0	174	35	1703
37063001100	Census Tract 11	965	530	0	0	13	2022
37063001303	Census Tract 13.03	933	308	0	92	5	3265
37063001304	Census Tract 13.04	597	549	0	0	0	1933
37063001400	Census Tract 14	591	413	0	0	0	1967
37063001501	Census Tract 15.01	1992	320	19	472	0	840
37063001706	Census Tract 17.06	2937	759	0	414	0	1249
37063001708	Census Tract 17.08	1265	595	0	59	0	3864
37063002008	Census Tract 20.08	3336	60	0	78	8	202
37063002013	Census Tract 20.13	3003	362	0	111	7	1357
37063002015	Census Tract 20.15	2879	1204	0	195	0	1443
37063000301	Census Tract 3.01	1390	317	0	83	0	951
37063001809	Census Tract 18.09	3132	768	0	221	0	2389
37063002019	Census Tract 20.19	3385	94	0	439	0	648
37063002020	Census Tract 20.20	5161	129	0	1089	90	2415
37063001806	Census Tract 18.06	2969	1005	0	22	15	3656
37063002024	Census Tract 20.24	4289	226	0	290	0	1164
37063980100	Census Tract 9801	0	0	0	0	0	0
37063001808	Census Tract 18.08	4562	587	0	580	0	5153
37063002200	Census Tract 22	1521	167	0	115	0	406
37063002026	Census Tract 20.26	1749	2168	0	128	0	5114
37063002021	Census Tract 20.21	2863	664	0	451	0	1057
37063002022	Census Tract 20.22	1802	135	0	333	0	1665
37063002023	Census Tract 20.23	1941	151	0	83	0	704
37063002025	Census Tract 20.25	2093	405	0	744	0	3357
37063001710	Census Tract 17.10	1817	830	0	172	0	2371
37063001711	Census Tract 17.11	1487	623	0	69	0	1977
37063001801	Census Tract 18.01	4104	2713	0	1	0	3924
37063000101	Census Tract 1.01	1350	466	0	3	11	2042
37063002007	Census Tract 20.07	2966	270	45	86	0	1659

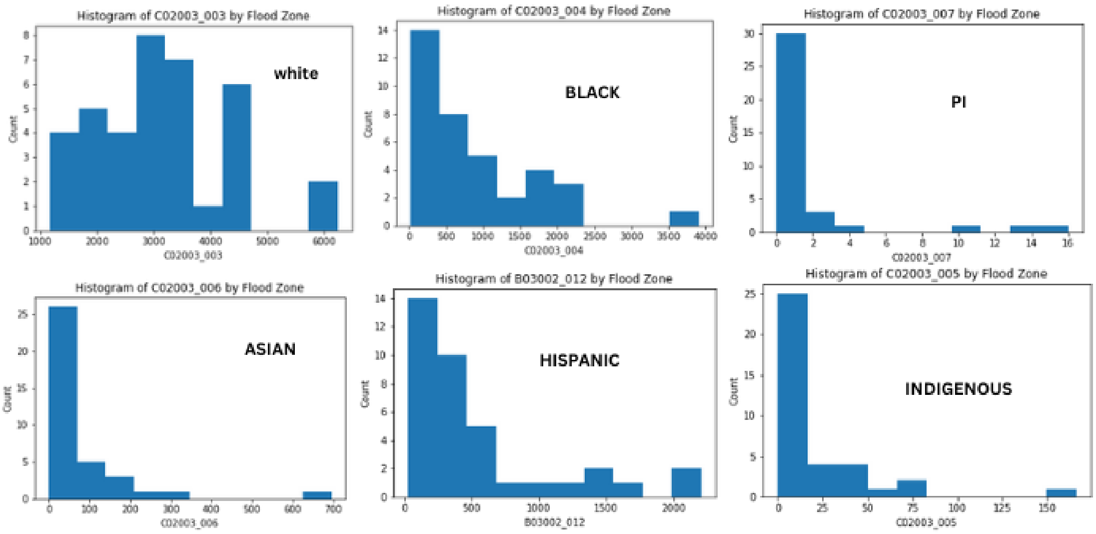
APPENDIX A: DEMOGRAPHIC TABLES

I have provided an example of a csv file that was generated from the flood hazard zone buffer. This is Durham County. This is a black-and-white image of a spreadsheet. The column names are GEOID, NAMELSAD, WHITE, HISPANIC, PI, ASIAN NATIVE, AND BLACK. This is meant to show how the data has been used to create population data.

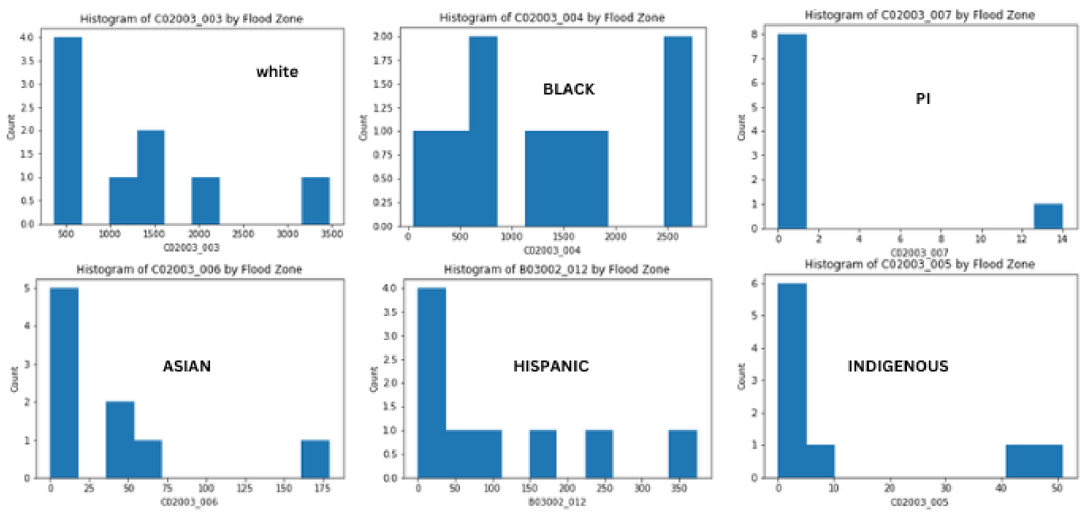
GEOID	NAMELSA	WHITE	HISPANIC	PI	ASIAN	NATIVE	BLACK		
3.71E+10	Census Tr	2581	224	6	416	27	1689		
3.71E+10	Census Tr	510	379	0	0	0	1201		
3.71E+10	Census Tr	542	395	0	71	0	1172		
3.71E+10	Census Tr	2537	43	0	628	56	473		
3.71E+10	Census Tr	2188	929	1	0	0	3688		
3.71E+10	Census Tr	719	311	0	718	72	622		
3.71E+10	Census Tr	3359	1024	0	418	108	1648		
3.71E+10	Census Tr	875	0	0	595	0	1151		
3.71E+10	Census Tr	4187	65	0	122	0	426		
3.71E+10	Census Tr	1408	631	0	867	0	1620		
3.71E+10	Census Tr	3009	161	0	102	23	398		
3.71E+10	Census Tr	1057	656	0	228	0	692		
3.71E+10	Census Tr	1361	665	0	203	0	993		
3.71E+10	Census Tr	3042	69	0	41	0	129		
3.71E+10	Census Tr	2991	1083	0	427	0	3023		
3.71E+10	Census Tr	2808	137	0	744	0	270		
3.71E+10	Census Tr	1608	1444	48	16	44	1666		
		161588	43051	168	15802	850	112965		SUM
		159486	50104	414	20606	7297	117964		CYT
		101	86	41	77	12	96		PIFHZ

APPENDIX B: COUNTY HISTOGRAMS

Alamance

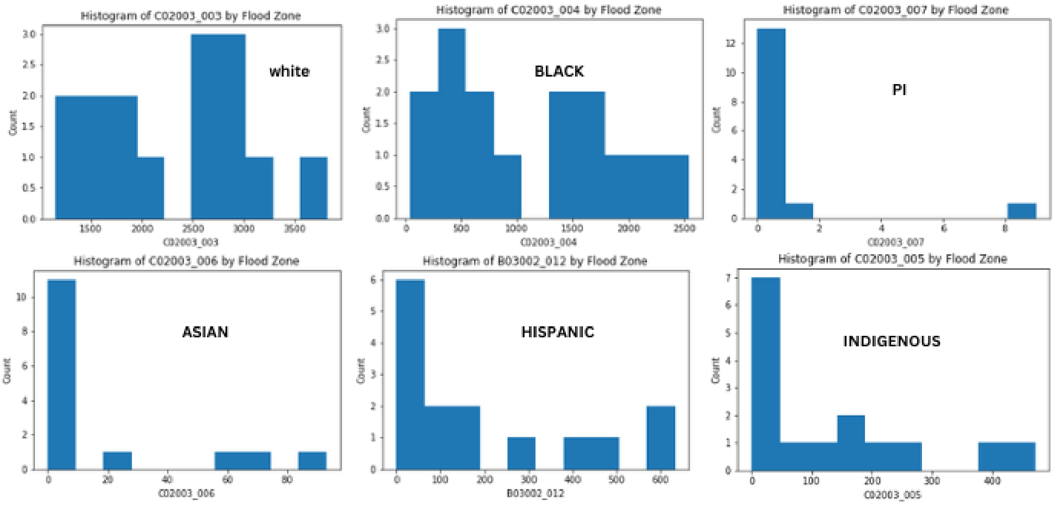


Anson

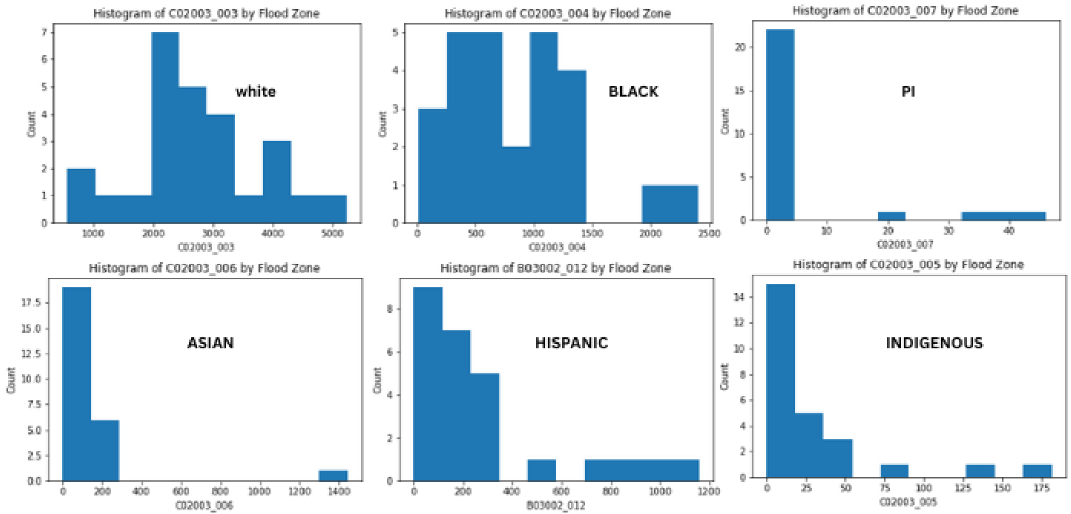


APPENDIX B: COUNTY HISTOGRAMS

Columbus

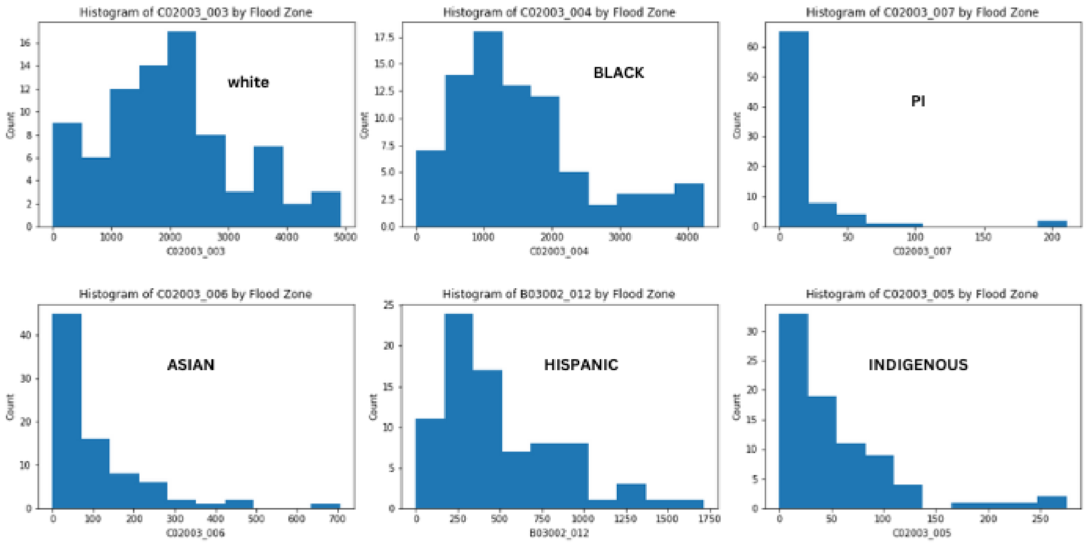


Craven

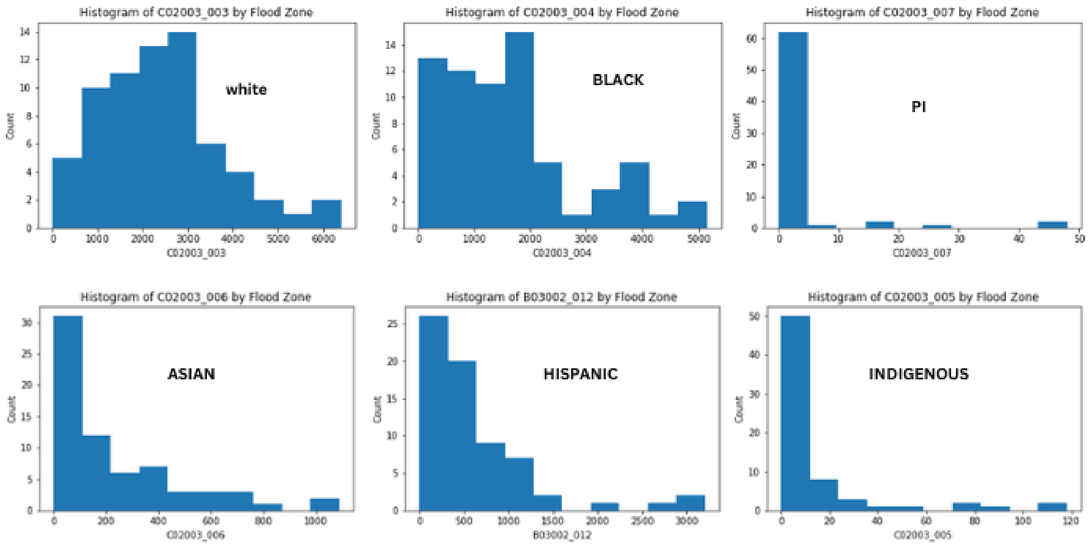


APPENDIX B: COUNTY HISTOGRAMS

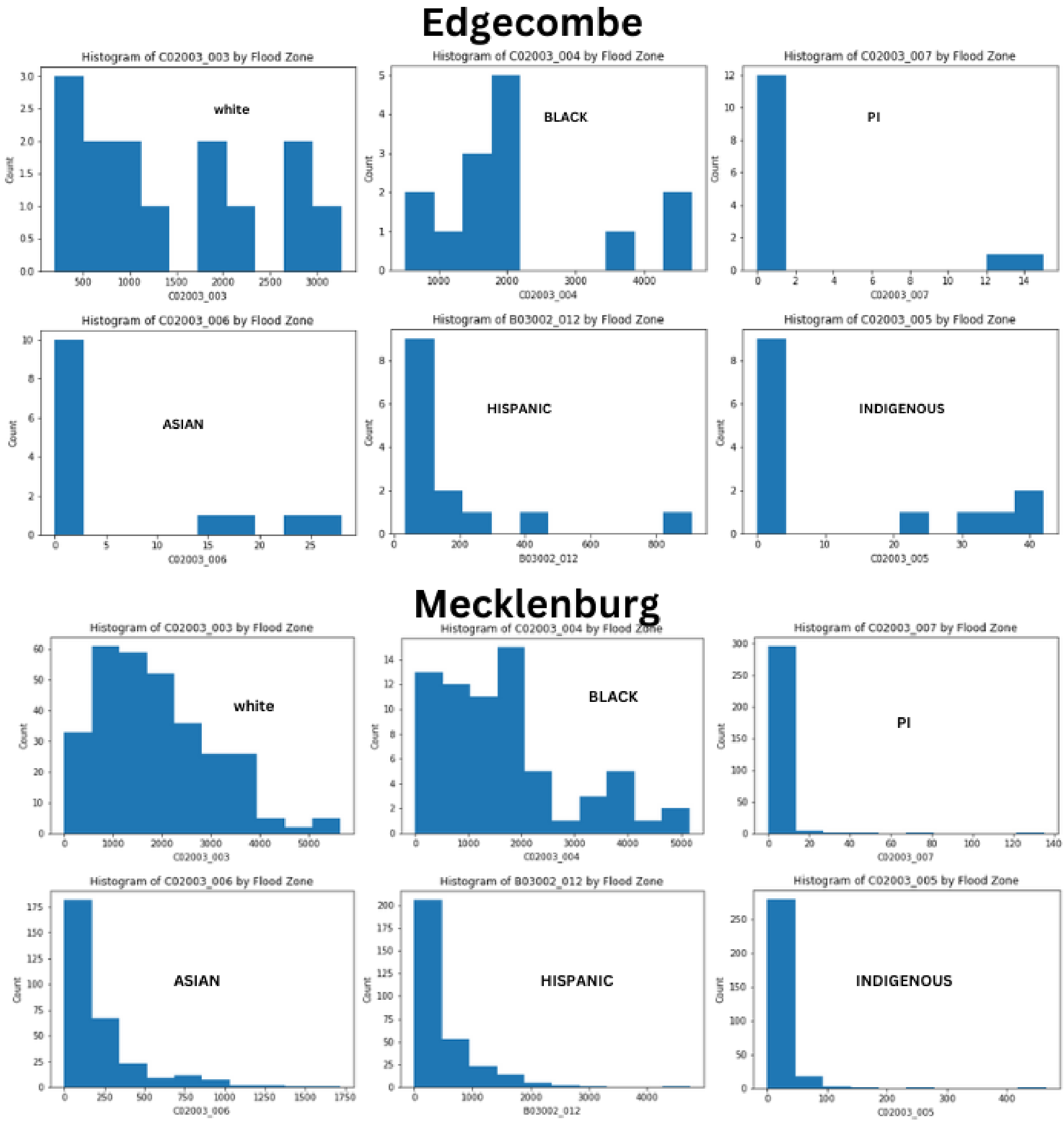
Cumberland



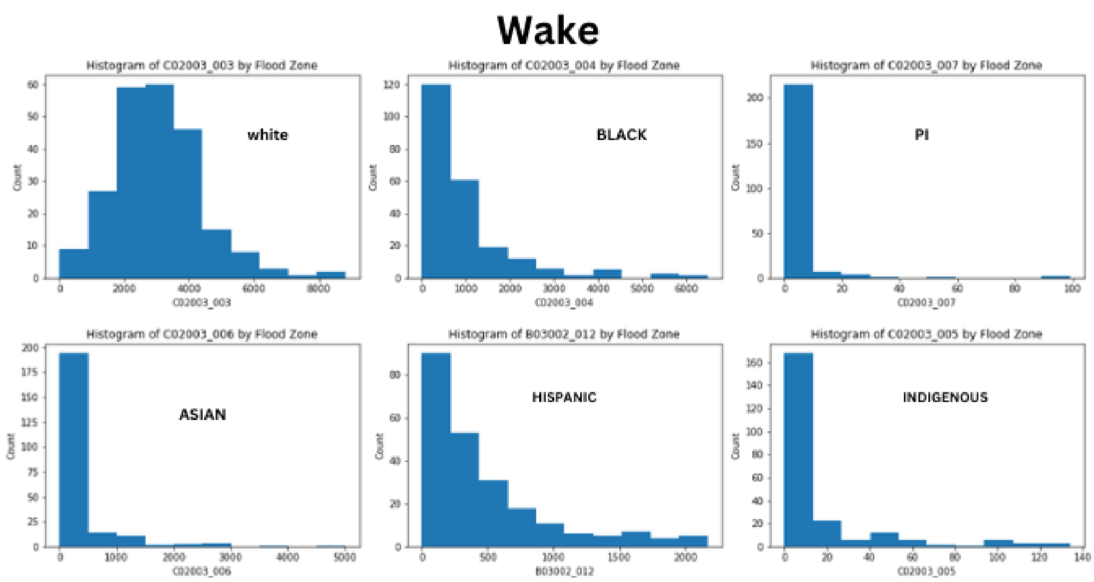
Durham



APPENDIX B: COUNTY HISTOGRAMS



APPENDIX B: COUNTY HISTOGRAMS



APPENDIX C: CORDEX ARRAYS

```
Difference in projected >=3 prec events: Model1 rcp85.CanESM2.CRCM5-UQAM <xarray.DataArray 'prec' (lat: 13, lon: 37)>
array([[ -3,   4,   9,  11,   3,   1,   9,   7,   2,  11,  16,  13,  22,
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         30,  22,   8,  -1,  16,  25,  33,   8,   1, -19, -22],
       [ -4,   8,   6,  13,   4,   9,  19,  16,   8,  13,  22,  17,  19,
         15,   9,  16,  11,  14,  17,  30,  30,  21,  16,  28,  32,  31,
         25,  31,  18,   6,   8,  19,  19,  19,  -2,  -3,  -5],
       [ -7,   0,   2,  11,  12,  16,  27,  17,   7,  14,  25,  22,  24,
         18,  10,  18,  12,   5,  12,  22,  18,  21,  25,  26,  24,  26,
         29,  40,  26,  22,   8,  26,  28,  15,  23,  13,   0],
       [  1,  -1,   9,  13,  14,  19,  18,  15,   2,   9,  10,  23,  18,
         19,  16,   2,  11,   5,   2,   9,   8,  17,  14,  24,  36,  32,
         35,  31,  24,  38,  20,  27,  25,  34,  24,  22,  12],
       [ -2,   6,   5,   7,   9,   8,  14,   4,  -2,   2,   9,   7,  11,
         12,  16,  18,  13,   7,   3,   8,  12,  28,  28,  27,  18,  33,
         30,  39,  26,  27,  22,  25,  39,  25,  12,  16,   8],
       [  1,   3,   0,   8,   4,   6,   6,   8,   2,   0,   6,   9,   5,
          3,   8,  16,  24,  18,   8,   5,   5,  17,  30,  26,  23,  39,
         30,  17,  21,  18,  27,  24,  38,  49,  30,  30,  24],
       [  6,   8,   5,   2,   3,   6,   2,  13,   6,   3,   8,  12,   7,
         -4,   4,   9,  15,   3,   6,   9,   3,   6,  18,  23,  21,  27,
         27,  22,  16,  16,  13,  28,  22,  37,  36,  30,  23],
       [  9,   8,   6,   8,   7,   5,  10,   9,   6,   9,   9,  11,   3,
         -1,   8,   8,   7,  11,  15,  11,  15,   9,  11,  20,  12,  18,
         31,  23,  25,  12,  11,  28,  39,  34,  27,  29,  29],
       [  0,   7,   3,   2,   1,   2,   4,   4,   5,   5,  10,  10,   6,
          7,   3,   5,   5,  11,  15,  10,  16,  12,  13,  20,  16,  13,
         22,  24,  22,  15,  14,  22,  29,  18,  20,  17,  29],
       [  5,   1,   4,   0,   4,   3,   4,   6,   7,   7,   7,   7,   4,
          8,   8,   3,   2,  11,  12,  15,  27,  18,  25,  26,  10,  15,
         13,  15,  11,   7,  14,  14,  13,  19,   5,  13,  12],
       [ 10,   6,   8,   4,   3,   8,   4,   6,   0,   4,   1,   5,   5,
         14,  19,  14,   3,   9,  19,  21,  16,  21,  23,  24,  14,  10,
         18,  14,  10,   3,  11,  10,  14,  10,  -2, -18,   8],
       [ 11,   9,  12,   4,   6,   8,   5,   1,  -1,   0,   1,   5,   5,
         12,  18,  12,   6,   7,  21,  24,  28,  22,  18,  24,  19,  10,
          7,  10,  17,  13,   2,   3,   5,  -6,   7,  -9,   8],
       [  3,   8,   6,   7,   3,   2,   1,   1,   3,  -1,  -1,  -1,   1,
          4,   5,   8,  -1,  13,  16,  17,  22,  16,  13,  15,  20,  13,
         10,  10,  17,  10,  13,   9,   0,  -4,  -6,   7,  11]])
Coordinates:
  * lat      (lat) float64 33.88 34.12 34.38 34.62 ... 36.12 36.38 36.62 36.88
  * lon      (lon) float64 -84.62 -84.38 -84.12 -83.88 ... -76.12 -75.88 -75.62
```

```
Difference in projected >=3 prec events: Model2 rcp85.GEMatm-Can.CRCM5-UQAM <xarray.DataArray 'prec' (lat: 13, lon: 37)>
array([[  6,   5,  -1,   1,  11,  14,   8,  14,  19,  25,  16,  19,  20,
         18,  20,  30,  15,  11,  16,  21,  17,  19,  15,  15,   7,   1,
         -1,  -3,   1,  19,  15,  17,  21,   8,  -2, -10,   3],
       [ -6,   1,   0,   0,  -2,  -3,  11,   9,  17,  17,  16,  23,  15,
          7,   7,  15,  18,  19,  16,  18,  16,   7,   5,   5,   2,  -2,
         -7,  -5,  -4,  16,  20,  19,  26,  19,  -2,  -6,   3],
       [ -7,   1,   6,  -2,  -3,  -2,  13,   9,  10,  15,  10,   9,  11,
         11,  10,  11,  12,  15,  11,   8,   4,  -5,  14,  12,   2,  -5,
         -7,   1,  -2,   0,  16,   3,  14,  27,  22,   7,   4],
       [-13, -16,  -5,  -5,  -3,   3,   2,  12,  10,  17,  16,   8,  14,
         13,  13,   9,  12,  11,  10,   8,   8,   3,   4,   7,  -2,   0,
         -5,  -6,  -1,   6,  10,   9,  18,  25,  25,  24,  17],
       [-15, -13, -10, -12, -14, -10,  -5,   5,   4,  16,  -1,   4,  -3,
          5,   7,  11,  14,   8,   8,  14,   6,  -2,   2,   0,  -4,  -8,
        -10, -12, -14,   1,   8,  17,  28,  18,  23,  21,   1],
       [-12, -11, -10, -14,  -8, -15, -15,  -7,   6,   7,  -4,   0,  -1,
         -4,  14,  10,  14,   6,  11,   8,  12,  -1,  -6,   1,  -2,  -9,
        -15, -18,  -9,  -1,   1,   8,  12,  24,  14,   9,   1],
       [ -9,  -5,  -5,   0,  -5,  -3,  -7,   6,   5,   7,   2,  -2,  -4,
         -1,   7,   7,  12,  15,  10,   1,   4,  -4, -11,  -7,  -7,  -4,
         -4, -10,  -6,  -2, -11,  -7,   2,   6,  11,   0,  -3],
       [ -4,  -4,   1,  -1,   7,   7,  10,   8,  10,  11,   5,  -1,  -8,
         -4,   2,   3,   6,  14,   6,   0,   3,   2,  -8,  -3,  -6,  -8,
        -11, -11,  -5,  14,   7,  -5, -13,   0,   6,  -6,  -4],
       [  1,   0,   6,  -1,   2,   1,   3,   9,   7,   8,  11,  -2,  -9,
          0,   9,   8,   7,   2,  -1,  -2,  -2,  -2,  -4,  -1,  -6,  -8,
         -8,  -4,   3,   7,  12,   1,  -1,  -2,   1,  -8,  -9],
       [  4,  10,   3,   1,  -3,   2,   4,   6,   5,   5,   9,   4,   3,
          0,  11,   2,  -4,   5,   2,  -2,  -5, -13,   3,  10,   3,   3,
        -11,  -7,   3,   7,  18,  15,   0,   2,  -3,  -4,   1],
       [  4,   2,   2,  -2,  -2,   0,   0,   2,   0,  -1,   2,   1,  -4,
          6,   6,   1,   0,  -3,   4,   6,  -1, -10,  -4,   4,  -5,  -5,
         -3,  -3,  -3,   8,   7,  11,  13,   7,   2,  -5,  -1],
       [ -4,  -7,  -8,  -7,  -7,  -4,   1,   5,   2,  -2,   5,   2,  -1,
          1,  -3,   4,  10,   6,   9,   1,  -7,  -3,  -3,   3,  -2,  -3,
          1,   0,   4,   6,   6,  11,  16,  12,   6,   0,   0],
       [ -6,  -6,  -5, -10,  -7, -10,  -5,  -1,   1,   1,   1,  -3,  -6,
         -1,   1,  -1,  -2,   8,  13,  16,   0,  -9,  -8,  -4,   2,  -2,
          3,   7,  10,   9,   4,  11,  12,  13,  16,  14,  11]])
Coordinates:
  * lat      (lat) float64 33.88 34.12 34.38 34.62 ... 36.12 36.38 36.62 36.88
  * lon      (lon) float64 -84.62 -84.38 -84.12 -83.88 ... -76.12 -75.88 -75.62
```

APPENDIX C: CORDEX ARRAYS

```
Difference in projected >=3 prec events: Model3 rcp85.GEMatm-MPI.CRCM5-UQAM <xarray.DataArray 'prec' (lat: 13, lon: 37)>
array([[  1,  -8, -13, -10,  -9,  -2, -10,  -5,  -1,   1,  11,  12,  14,
          9,  10,   6,  -8,  -2, -12,   2,   9,   1,   2,  -1,  18,   8,
         28,  24,  20,  31,  19,  20,  34,  22,  12,   8,  14],
       [ -2,  -7, -18, -12, -18,   4,  -3,   0,  10,   6,   6,   6,   4,
         14,   2,   5,  -4,  -9, -18,   2,   8,  -1,  -5,  -8,   8,  11,
         16,  32,  28,  20,  27,  22,  26,  34,  31,  17,  24],
       [ -2, -14, -14, -17, -17, -11,  -7,   3,   5,   0,  -9,  -3,  -2,
         -3,  -3,  -9, -10, -10, -17,  -8,  -1,  -3,  -8,  -7,   4,   3,
          8,   8,  29,  26,  21,  21,  24,  28,  36,  43,  35],
       [  0, -11, -10, -12, -17,  -1,   1,  13,   3,   4,  -9,  -3,  -2,
        -14, -18, -19, -10,   0, -11, -14,  -7, -13, -12,  -6,  -3,   2,
         -1,  16,  29,  29,  23,   8,  25,  26,  22,  25,  37],
       [  0,  -4,  -8,   2,  -2,   6,  13,  20,   8,  -2, -15,  -9,   1,
        -11, -18, -14, -11,   1,  -5, -11, -15, -20, -16,  -5,  -5,   3,
          6,  11,  24,  35,  26,  24,  26,  29,  39,  27,  33],
       [  1,   3,   2,  -3,  -3,  -4,   1,  16,  17,  -1, -12, -10,  -7,
          2, -13,  -9,  -9,  -4,  -8,  -8,  -5, -13, -13,  -6,  -6,   4,
         12,  13,   8,  15,  22,  19,  16,  23,  33,  28,  36],
       [  5,  -2,   4,   2,  -1,  -2,  -4,   4,  15,   5,   0,  -8,  -2,
          3,   2,  -2, -12,   1,  -5,  -6,  -2,  -8,  -2, -11,   4,   6,
         15,  14,   7,  21,  24,  16,   0,  16,  29,  29,  34],
       [  1,   1,   0,   0,  -8,  -9,  -8,  -7,   0,   7,   4,   1,  -8,
          5,   6,  -5, -10,   1,   4,   3,  -7,  -6,  -1,  -7,  -7,   4,
         18,  21,  20,  27,  19,  27,   9,  12,  16,  25,  21],
       [  1,   1,  -3,  -3,  -7,  -7,  -8,  -4,  -3,  -5,  11,  -1,   4,
          1,   9,  -7,  -1,   0,   9,   8,  -5,  -8,   2,   4,   7,  12,
         14,  26,  27,  20,  25,  20,  22,  18,   8,   5,   6],
       [  4,  -2,  -4,  -5,  -6,  -4,  -6,  -9,  -8,   0,   6,   8,   1,
          6,   5,   3,   2,  10,   9,   7,   1,  -5,   0,   7,   6,  10,
         12,  15,  22,  19,  23,  22,  27,  24,  11,   4,   3],
       [ -1,  -1,  -1,   3,  -3,   1,  -3,  -4,  -3,   3,   9,  11,   8,
         10,   7,  13,   7,  10,   6,  11,   2,   0,  -2,   2,   4,   5,
         10,   7,  11,  13,  17,  19,  23,  14,  13,   1,   1],
       [  4,  -2,   0,   2,   2,  -1,   1,  -1,   6,   6,   6,   7,  10,
          6,  14,  14,   6,   1,   4,   5,   5,   4,  -5,  -9,   0,   2,
          5,  -2,  10,  14,  12,  13,  14,  14,  14,   3,  -2],
       [  1,   0,   0,   2,   0,   2,   2,   6,   3,   2,  10,  10,  11,
         12,   8,   7,   7,  -2,   4,   6,  -2,  -2,  -2,  -9,  -1,   6,
         -3,   3,   0,   6,   6,  14,  11,  16,   7,   8,   5]])
Coordinates:
  * lat      (lat) float64 33.88 34.12 34.38 34.62 ... 36.12 36.38 36.62 36.88
  * lon      (lon) float64 -84.62 -84.38 -84.12 -83.88 ... -76.12 -75.88 -75.62
```

```
Difference in projected >=3 prec events: Model4 rcp85.GFDL-ESM2M.WRF <xarray.DataArray 'prec' (lat: 13, lon: 37)>
array([[ 7,  9,  8,  2,  0,  3,  2,  7,  5,  5,  0,  2,  3,  8, 12, 10,
        15, 16, 12, 12,  7,  7, 11,  9, 16,  0,  4,  8, 14, 15, 15, 12,
        19, 23, 21, 16, 10],
       [ 2,  7, 11,  8,  4,  6,  9,  2,  4, -2,  5,  8,  5,  7, 10, 16,
        13, 17, 17, 11,  0,  6,  5,  9, 15, 27, 10,  9, -1, 13, 19, 21,
        14, 11, 13, 18, 12],
       [ 8, 11, 10,  5, 16, 16, 11,  8,  6,  2, -2,  3, 10,  7, 14, 18,
        20, 19, 20, 13,  6,  6,  5,  2, 13, 18, 19,  6, -5,  2, 20, 21,
        29, 13, 10, 15, 20],
       [16,  9, 10, 10, 15, 16, 30, 23, 13,  4,  1,  2, -2,  9, 11,  9,
        15, 22, 22, 17,  9,  8, 12,  4,  5,  9, 13, 10,  2,  3, 12, 11,
        17, 18, 19, 10,  3],
       [ 6,  7,  7,  8,  9, 11, 26, 28, 28, 13,  2,  2,  7, -4, -2,  2,
         9, 15, 16, 16, 14, 10,  8, 10, 11,  8, 12,  8,  4, -5,  2,  3,
        14, 18, 11, -2,  4],
       [-1,  4,  3,  0,  1, 10, 11, 13, 16, 23,  5, -3,  1,  0, -1, -2,
        -3,  5,  8, 11, 15, 10, 13, 11,  8, 10, 12,  5,  0, -3, -9, -4,
         7,  3,  3,  0,  0],
       [ 5,  0,  0,  0,  2,  2,  3,  4,  7,  8,  4,  9,  4, -4, -1, -1,
        -4, -2,  8, 11, 11,  8,  6, 13,  9, 10,  9,  8, -1, -3,  0, -5,
        -3, -4, -1,  5,  4],
       [ 6,  1,  2,  2,  1,  2,  2,  2, -7, -1,  0,  0,  3, -1,  0, -2,
        -4,  0, -3,  2,  8, 16, 17, 14,  7,  9,  5,  2, -3, -1,  2,  4,
         0,  3, -4,  2,  8],
       [11,  7,  4,  5,  2,  3,  3,  2, -1, -6,  2, -3, -1,  1,  0, -6,
        -3, -4, -1, -1,  9, 11, 13, 14, 15, 15, 17, 13,  8,  6,  3,  4,
        -4,  1, -1,  5,  4],
       [ 5,  7,  7,  5, 11,  4,  1,  4,  0,  1, -4,  1,  7,  4, 11,  9,
        -3,  2,  2,  0, -1,  8,  9, 11,  9, 17, 15, 16, 16,  8,  3, -1,
         3,  0, -2,  9,  2],
       [-4,  1,  3,  7,  9, 12,  9,  6,  5,  2, -1, -3, -4,  0,  8,  9,
         3,  2, -2, -2, -3,  4,  7, 12,  8, 11,  9, 10, 11, 10,  2,  3,
         4,  5,  1, -1,  7],
       [ 6,  6,  6,  4,  3,  6, 12, 11,  4,  2,  3,  2,  0, -6, -7,  0,
         5,  7,  3,  0,  2, -1,  2,  8, 12, 10, 10,  9,  9,  6, 12, 10,
         0,  3,  1,  1, -3],
       [ 2,  4,  6,  5,  9,  6,  8,  2,  6,  4,  4,  0,  1, -3, -5, -8,
        -5, -3,  1,  2, -1, -1,  3,  6,  3,  7,  7,  9,  9,  1,  7, 11,
         7, -5, -5, -4, -3]])
Coordinates:
  * lat      (lat) float64 33.88 34.12 34.38 34.62 ... 36.12 36.38 36.62 36.88
  * lon      (lon) float64 -84.62 -84.38 -84.12 -83.88 ... -76.12 -75.88 -75.62
```

APPENDIX C: CORDEX ARRAYS

```
Difference in projected >=3 prec events: Model5 rcp85.HadGEM2-ES.WRF <xarray.DataArray 'prec' (lat: 13, lon: 37)>
array([[18, 20, 19, 18, 16, 14, 14, 16, 11,  4, 13,  5, -5,  3, -1,  1,
         6,  4,  1, -1,  0,  5,  9, -4,  2, 11, 16, 17, 12,  5,  6, 21,
        15, 18,  8, 19, 12],
       [23, 26, 23, 23, 21, 23, 22, 16, 15,  4,  3,  3,  6,  5,  6,  7,
        13,  9,  6,  3,  3, 11, 12, 16,  6,  6, 20, 14,  4, 12,  4,  8,
        14, 12, 22, 32, 23],
       [20, 28, 27, 34, 32, 26, 24, 23, 16, 11,  8,  9,  5,  9, 10,  7,
        10, 11, 13, 16, 14, 15,  8, 16, 19, 20, 19,  7,  3, -3, -4,  5,
        13, 27, 21, 35, 28],
       [15, 20, 22, 26, 35, 37, 24, 27, 23, 17,  7,  2,  7,  6,  3,  0,
         7, -1, 12, 17, 19, 18, 17, 15, 16, 19, 18, 20, 15, 13,  7, 11,
        11, 20, 26, 36, 36],
       [ 3,  6, 10, 29, 28, 31, 37, 46, 38, 28, 16, 10,  2,  2, 10,  7,
         7,  4,  2, -1,  9, 18, 21, 21, 18,  9, 11,  9, 15, 20, 14, 21,
        20,  8, 22, 16, 15],
       [ 8, 13, 17, 14, 22, 23, 29, 36, 37, 29, 31, 20,  7, -2,  7, 11,
         9, 13, 11, 11,  5, 14, 10, 11, 18,  7,  5, 10,  3,  1, 10, 11,
        16, 10, 19, 19, 18],
       [15, 18, 17, 17, 13, 15, 11, 21, 25, 27, 27, 28, 19, 13, 10,  8,
        10, 14, 12,  8, 13,  8, 13, 11, 15, 11, 10,  6,  3, 10, 11, 15,
         8, 15, 17, 22, 28],
       [13, 21, 19, 13, 20, 16, 11, 10, 18, 25, 32, 33, 27, 18,  9,  8,
         9, 11, 12, 10, 12, 15, 10,  9, 14, 13,  9, 11,  2,  4,  0, 11,
        10, 23, 17, 17, 14],
       [14, 18, 19, 17, 20, 17, 14, 14, 17, 18, 27, 34, 26, 24, 12, 21,
        16,  9, 12,  8,  7,  9,  8, 12,  7, 10, 13,  9, 13, 11,  5,  1,
        -3,  1,  9,  4,  2],
       [ 8,  9, 12, 18,  9, 14, 17, 17, 15, 15, 12, 26, 28, 27, 17,  6,
        12, 10,  8,  6,  7,  9,  6,  3,  4,  7,  4,  6, 10, 16, 14, 10,
        -2, -4,  4,  1,  4],
       [ 7, 11,  6, 10, 12,  9, 13, 13, 11, 10,  7,  8, 19, 30, 22, 17,
        12,  7,  6,  7,  9, 11,  6,  0,  3,  6,  3,  3,  4, 10, 10,  8,
         0,  0,  2,  4, 14],
       [15, 13, 10, 12, 11,  6,  8,  6,  1, -5,  2,  3, 10, 18, 24, 20,
        17,  8,  6, 12, 15, 11,  5,  0,  4,  5,  2,  2,  1,  8,  8, 11,
         8,  5,  6,  3,  5],
       [10, 11, 15, 14, 11,  9,  3,  5, 10,  7,  6,  5,  0,  3, 10, 12,
        11,  9,  8,  5,  2, 10,  2,  1,  2,  5,  1,  1,  3,  6,  2,  9,
        12,  9, 11,  2,  3]])
```

```
Difference in projected >=3 prec events: Model6 rcp85.HadGEM2-ES.RegCM4 <xarray.DataArray 'prec' (lat: 13, lon: 37)>
array([[ 10,   9,  17,  19,  20,  15,  12,  10,   3,   7,  14,  12,  11,
         15,   8,   9,  17,  11,  11,  -1,   3,   9,   5, -11,   3,  12,
         -2,   0,   4,   1,  -9, -14,  -2,  -7,  -2,  -4,  -1],
       [  7,  12,  19,  23,  17,  11,   7,  14,   0,   4,  13,   5,  12,
          7,   9,   6,   7,   6,  10,  11,  16,  18,  14,   6, -13, -14,
          5,   0,   7,   0,  -3, -10, -17, -24, -10,  -9,  -2],
       [  3,   8,  19,  23,  20,  11,  15,  17,   9,   2,   2,   7,   5,
          6,  13,   4,   0,   4,  11,  19,   8,   9,  14,  18,   7,  -2,
         -7, -10,   5,   5,  -2,  -6, -11,  -4,   5,   2,   0],
       [ -3,   2,  12,  12,  12,  10,   9,   7,  14,  11,   1,   6,  10,
          9,  -2,   2,   8,  11,  11,   9,  11,   8,  11,  16,   8,  10,
          8,  -1, -12,   4,   3,  -2, -15, -12,   3,   8,   3],
       [ -1,  -3,   7,   6,   5,   1,  -1,   1,  10,  10,   3,   6,   3,
          5,   2,  12,   9,   8,  11,   6,  10,   4,   9,   5,   8,  16,
          6,  -8,   6,  14,   9,  -6,  -8, -13,   5,   3,  -9],
       [  1,   0,  -4,   2,  13,  14,   9,   5,   6,   3,   5,   0,  -2,
         -3,   1,   8,  13,   1,   5,   6,   3,   2,   1,   7,   3,   5,
          2,   0,   1,  10,  24,   6,  17,   7,   4,   4,   4],
       [  6,   2,  -1,  -3,  -1,   0,   3,  -3,  -9,  -1,  -4,   1,  -3,
          1,   2,   0,   1,  -5,   7,   5,   5,   4,  13,   8,   7,  11,
          7,   9,   7,   4,   3,   7,   6,   8,   6,   2,   1],
       [  1,   2,  -2,   1,  -2,   2,   5,  -4,  -6,  -5,   0,  -2,   2,
          4,   6,   3,   0,  -4,   2,   5,   2,   6,   4,   7,   0,  13,
          9,   8,   7,   4,   3,  -1,  18,   6,   3,  -3, -10],
       [ -1,   1,  -1,  -1,   1,   3,   2,   1,   1,   1,   0,   1,   2,
         -5,   3,   6,   7,   1,  -2,   1,   1,   0,  -5,  -1,   4,   9,
          9,   9,  10,  11,  11,   3,   4,  -8,  -6,   3,   4],
       [ -4,  -2,   1,  -1,   1,  -4,   0,   0,   0,  -1,  -3,  -3,  -1,
         -5,  -2,   7,   4,   3,  -5,   0,   5,   3,  -6,  -2,   2,   9,
         12,   9,   6,  14,  -1,   1,  -1,  -8, -22,  12,   8],
       [ -4,  -2,   3,  -4,  -2,  -1,   3,   3,   1,  -1,   2,  -6,  -7,
        -12, -11,   1,   2,   6,   1,   0,   6,   3,  -5,  -5,  -3,   3,
          8,   5,   3,   6,   0,   2,   1,  -9, -16,   7,  10],
       [  0,  -4,  -1,  -1,  -8,  -1,   1,   1,   1,   1,   2,   1,  -4,
         -2,  -3,   1,   6,   0,   4,   2,   1,   0,  -2,  -5,  -4,  -2,
          2,   6,  -3,   1,  -3,   8,   6,   6,   3,  12,   1],
       [  1,   2,  -1,  -1,  -3,  -2,   1,   0,  -2,   0,   1,   0,  -2,
          0,  -4,   1,   8,   5,   6,   4,   9,  -3,   0,  -4,  -2,   0,
          1,   5,  -4,   3,   1,   6,  11,  -5, -10, -12,   2]])
```

APPENDIX C: CORDEX ARRAYS

```
Difference in projected >=3 prec events: Model7 rcp85.MPI-ESM-LR.WRF <xarray.DataArray 'prec' (lat: 13, lon: 37)>
array([[  5,   1,   2,   4,   0,   5,   7,   6,   5,   7,   4,   3,   2,
          4,   3,   2,   3,   0,   2,   2,   1,   0,   2,   3,  10,  10,
         14,   8,  -4,  -8, -12,  -5,  -9,  -6,   4,   8,   7],
       [  7,  11,   7,   1,  -1,   0,   3,   4,   9,   7,   6,   7,   8,
          5,   5,   1,   2,   3,   7,  10,  10,   8,   2,   6,  11,  12,
         18,  17,   8,   3,   4,  -3,   5,  -2,   5,  -1,   3],
       [ 14,  13,  17,  11,  12,   4,   4,   5,   4,   7,   7,   5,   5,
          4,   2,  -1,  -1,   1,   8,  10,  11,  12,  15,   9,  14,  10,
         12,   5,   2,   8,   5,  12,   8,   9,   8,   5,  11],
       [ 13,  12,   8,   9,  14,   8,   7,  10,  10,   6,   6,   5,   7,
          7,   4,  -2,  -3,  -8,  -5,   1,   3,   9,   9,  13,  14,   8,
          1,   8,   1,  15,  14,   6,  11,   3,   4,  12,   6],
       [ 12,  11,   8,   6,   9,   6,   0,  11,   7,   4,   8,   8,   8,
          9,  10,  -1,   1,  -8,  -1,  -3,  -1,   5,   9,  11,  11,  11,
          3,   4,   7,  13,  10,  11,  11,   4,   5,   3,   3],
       [  7,   5,   9,  10,   5,   1,   1,   3,   5,   6,  -1,   4,   8,
          9,   6,   1,   4,  -2,  -3,   2,  -4,   2,   0,   5,   9,   7,
          3,   5,   6,   2,   2,   1,   1,   3,   3,  -3,  -7],
       [  8,   7,   9,   4,   5,   9,   5,   6,   4,   7,   7,   5,   4,
          7,   9,   8,   2,   3,  -2,  -2,   0,   6,   1,   4,   9,   9,
          5,   7,   4,   1,   8,   4,  11,   3,   5,  -6,  -7],
       [ 11,   7,   9,  -1,   1,   3,   2,   0,   4,  10,   6,  10,  11,
          8,   8,  12,  12,   8,   2,  -2,   2,   2,   1,   3,   4,   5,
          1,   0,   0,   0,  -1,   7,   6,  14,  16,   9,  -4],
       [  5,   5,   2,   2,   2,   2,   0,   3,   3,   4,   5,   8,  13,
          8,   4,   8,   8,   9,   6,   3,   1,  -1,   1,  -2,   1,   4,
          1,  -5,  -3,  -3,  -3,   2,   0,   9,   9,  17,   4],
       [  2,   3,   7,   5,   4,   2,   3,   2,   6,   8,   7,  11,   8,
          9,  10,   6,   9,  12,  11,   2,   2,   0,   1,   4,  -2,   1,
          2,   0,  -4,  -4,  -1,  -2,  -3,   8,   6,   3,  13],
       [  3,   6,   5,   5,   6,   2,   1,   6,   5,   6,   6,   5,  12,
          5,   9,  13,   8,  12,   9,   7,   2,  -2,  -2,   4,  -3,   1,
          3,  -5,  -6,  -7,  -7,  -4,  -4,   1,  -7,  -9,  -2],
       [  3,   1,   0,   1,   5,   4,   3,   5,   3,   2,   1,   5,   5,
          8,   7,   7,   8,   4,   6,   0,   4,   5,  -1,   1,   4,   3,
          5,   6,  -2,  -6,  -6,  -1,   4,   5,  -2,  -5, -10],
       [  4,  -1,  -3,   2,   2,   1,   1,   4,   5,   2,   0,   1,   2,
          0,   3,   7,   9,  13,  14,   3,   8,   6,   4,   0,   3,   4,
          4,   6,   6,   1,   0,  -4,  -3,   2,  -2, -10, -13]])
Coordinates:
  * lat      (lat) float64 33.88 34.12 34.38 34.62 ... 36.12 36.38 36.62 36.88
  * lon      (lon) float64 -84.62 -84.38 -84.12 -83.88 ... -76.12 -75.88 -75.62
```

```
Difference in projected >=3 prec events: Model8 rcp85.MPI-ESM-MR.CRCM5-UQAM <xarray.DataArray 'prec' (lat: 13, lon: 37)>
array([[12, 10,  8, 12, 19, 13, -1,  3,  9,  5,  4,  7, 10,  4, 11, 11,
         6,  6, 11, 16, 16, 19, 27, 33, 28, 23, 39, 32, 17, 20, 16,  8,
        12, 10,  0, -2,  2],
       [ 9, 10, 19, 13,  7,  4,  4,  3, -5,  5,  1,  7,  3,  3, 19, 19,
        26, 23, 15, 18, 24, 24, 23, 24, 30, 34, 36, 40, 33, 27, 24, 18,
        13, 14,  8, 19, 23],
       [ 4, 12, 14, 16,  8,  6,  6,  3,  0,  5,  2,  6,  6,  9, 21, 27,
        15, 18, 22, 21, 21, 33, 34, 31, 24, 34, 33, 28, 29, 27, 34, 28,
        27, 31, 15, 20, 26],
       [ 8,  9, 10, 15, 17, 20,  8,  5,  6,  1, -4, 11,  7,  9, 18, 19,
        18, 15, 15, 15, 22, 29, 32, 27, 25, 25, 30, 33, 32, 27, 31, 24,
        24, 26, 27, 26, 27],
       [11, 13, 12, 26, 28, 19, 17,  7,  4,  3,  1,  5,  9, 12, 11, 15,
        16, 15, 20, 19, 24, 24, 23, 17, 23, 22, 31, 40, 37, 37, 33, 25,
        10, 28, 36, 32, 23],
       [11, 20, 18, 22, 20, 11, 14, 18,  4, 11,  3, -2,  5,  5, 11,  8,
         7, 15, 18, 17, 21, 24, 20, 23, 25, 18, 19, 31, 35, 36, 41, 29,
        23, 17, 14, 27, 30],
       [10, 15, 14, 21, 23, 21, 16, 14, 10,  9,  6,  1,  3,  5,  8,  7,
        13, 14, 17, 21, 20, 22, 18, 22, 16, 17, 15, 12, 20, 25, 23, 24,
        18, 17, 25, 31, 31],
       [14, 10,  4, 14, 11, 10, 10,  3,  0, -3,  1,  5, -1,  2,  4, 14,
        16, 19, 18, 12, 12, 18, 17, 19, 24, 19,  9,  5,  1,  7, 13,  4,
        15, 20, 25, 31, 19],
       [-1,  5,  7,  6,  5, 11,  7,  3,  5,  6, -6, -2, -2,  3,  5, 10,
        20, 16, 13, 13, 16, 17, 15, 12,  6, 18, 12, 10,  4, -1,  0,  8,
        14, 12, 18, 31, 26],
       [ 1,  5,  3,  5,  5, 10, 13, 11,  4,  4,  6, -1,  5,  3, 12, 11,
        14, 20, 20, 20, 17, 12, 19, 20, 14,  9, 13,  0, -1,  1,  5,  5,
        12, 10, 24, 27, 31],
       [ 2,  8,  2,  2,  4, 11, 12,  9,  7,  3,  3,  2,  3,  2,  4,  9,
        12, 16, 17, 13, 15,  7, 15, 11, 14,  7,  6,  6,  4,  4,  0,  0,
        14, 15, 21, 16, 24],
       [ 4,  2,  3,  3,  6,  8,  7, 12,  9, 10,  6,  5,  2,  4,  6, 15,
        16, 17, 19, 15,  9, 16, 19, 13, 16, 11,  2,  9, 10,  9,  3, -2,
         6, 15, 25, 20, 19],
       [ 3, -2,  4,  8, 10, 14,  8,  6, 11, 14, 11,  6,  3,  0,  2,  4,
         8, 15,  8, 13, 19, 17, 13, 14, 10,  9, 10,  6, 13, 13,  0, -6,
        -3,  2,  8,  6, 11]])
```

APPENDIX C: CORDEX ARRAYS

```
Difference in projected >=3 prec events: Model9 rcp85.MPI-ESM-LR.CRCM5-OUR <xarray.DataArray 'prec' (lat: 13, lon: 37)>
array([[  7,  11,   6,  11,  12,  11,  11,  15,  18,  23,  22,  18,  20,
         11,   8,   3,  13,  18,  21,  11,   5,  16,  15,  23,  19,  14,
          1,   4,  -2,   8,  23,  22,  25,  20,  19,   8,   4],
       [  5,   7,   2,   4,   0,  -3,   7,   9,  17,  28,  21,  17,  14,
         19,   7,   8,   9,  11,  10,   4,   5,   7,  19,  19,  21,   8,
          4,   0,   6,   5,  15,  30,  24,  28,  17,  17,  14],
       [  5,   7,   5,   6,  -3,  -2,   0,   5,  10,  16,  16,  18,  14,
         19,  14,   7,   5,   8,  -2,   2,  -5,   4,  10,  14,  25,  32,
         21,  -1,  -6,   4,   5,  14,  13,  17,  19,  14,  11],
       [ -2,   2,   7,   9,  14,  12,   9,  13,  11,   6,  12,   8,   6,
         10,  12,   9,   7,  -4,  -2,  -5,  -8,  -6,   7,  10,  20,  22,
         17,   9,   3,   0, -11,   1,  16,  23,  20,  11,   9],
       [  4,   2,   3,   2,  12,   8,  15,  12,   9,   3,   3,  -1,  -4,
          6,   3,  -6,   3,   1,  -8,  -5, -10,  -6,   4,   3,  12,  16,
         11,  11,   9,   2,   2, -10,   2,   6,  11,   4,   1],
       [  3,  -1,   0,   7,   2,   5,  10,  10,   0,  -1,   1,  -4,  -8,
          0,   1,   6,   3,  -4,   0,  -8, -17,  -7,   2,   4,   6,  16,
         21,  16,  12,  15,  14,  11,   3,  -1,  10,  24,  10],
       [  4,   0,   0,   5,   4,  -1,   0, -11,  -8,  -5,  -5,  -2,  -3,
          2,   6,  -2,   0,  -4,   4,  -1,  -5,  -7,  -3,  -4,   6,  14,
         16,  27,  29,  21,  14,  17,  10,  19,  19,   8,  18],
       [  8,   0,   3,   2,   5,  -1,  -1,  -5,  -7,  -4, -13,  -7,  -3,
          0,   4,  -3,   2,  -3,   6,   2,  -3,  -6,  -7,  -7,  -1,   7,
          7,  14,  18,  16,  19,  20,  16,  27,  27,  16,  15],
       [  3,  -4,  -1,   5,   2,   1,   3,   0,  -2,  -1, -12,  -9,  -5,
          2,  12,   2,   5,   5,   4,  10,  11,   4,  -4,  -3,   0,  -3,
         -3,   5,   7,   8,   9,  19,  23,  15,  22,  19,  30],
       [ -4,   0,   7,   8,   5,   1,   1,   3,   1,   1,  -2,   0,  -1,
          2,  13,   4,   3,   1,  -2,   2,   3,   5,   3,   5,  -5,  -9,
         -8,  -1,   8,   9,  10,  14,  13,  12,  12,  10,  23],
       [  3,   4,  10,   9,   1,   6,   6,   3,   4,   2,   1,   2,   6,
          2,   7,   2,   3,   4,   2,  -3,  -4,  -3,   2,   2,   1,  -3,
         -2,  -5,   3,   6,   7,  13,  16,  21,  23,  15,  25],
       [  7,   6,   8,   6,  -1,  -1,   1,   5,   5,   3,   0,   2,   2,
          5,   4,   1,   2,   0,  -1,  -4,  -7,  -6,  -6,   1,   6,  -4,
         -8,  -4,  -8,  -2,   6,   7,   8,  20,  17,  16,  16],
       [  4,   1,   2,   3,  -1,  -2,  -3,  -3,   1,   2,   1,   1,   1,
          0,   1,   3,   1,  -4,  -4,  -4,  -8, -13,  -9,  -3,  -2,  -3,
         -1,  -5,  -8,  -5,   0,   3,   7,  11,   6,   3,   7]])
```

```
Difference in projected >=3 prec events: Model10 rcp85.CanESM2.CanRCM4 <xarray.DataArray 'prec' (lat: 13, lon: 37)>
array([[  7,  12,   6,  -1,   5,  -2,   4,   9,   5,  15,  15,   6,   8,
         -2,  -1,   7,   6,   5,  10,  -1,   1,  10,   6,  12,  16,  13,
         13,  24,  23,  17,  10,  31,  19,  12,   0,   3,   1],
       [  5,  11,  13,  10,  -1,   9,  17,  19,  15,  14,  18,  14,  -7,
          0,   7,   4,  18,  22,  17,   4,   3,   2,  18,  12,  18,  23,
         19,  19,  24,   7,  15,  31,  22,  17,  10,   6,  17],
       [  7,   8,  11,  10,   5,  13,  17,  22,  18,  20,  13,   9,  -1,
          5,   4,  12,  14,  17,  25,  16,  17,   9,   6,   7,   9,  12,
         12,  12,  18,  20,  16,  20,   9,  26,  23,   5,  12],
       [ 14,   4,   2,   8,   2,   1,   5,   5,  17,  27,  16,  13,   8,
         11,   3,   4,   4,  15,   7,   6,   6,  15,  27,  18,   7,   8,
          6,  -3,   2,  11,  20,  16,  17,  11,  14,  13,   3],
       [ 22,  15,   9,   3,  10,  10,   7,  14,  18,  21,  24,  18,   4,
          9,   9,  14,  11,   7,  11,  16,  12,  17,  18,  21,  10,  13,
         19,  15,   8,  16,  14,  24,  16,   6,   1,   4,  18],
       [  6,   7,   6,  10,  12,  12,   6,  18,  14,  17,  17,  11,  14,
         16,   5,  10,  10,  13,  25,  22,  29,  32,  22,  23,  28,  15,
         28,  19,  17,  15,  18,  21,  14,  16,   4,  -7,   7],
       [ 19,  17,  11,   9,   7,   4,  -4,   3,  16,   7,  25,  16,  14,
          2,   1,   6,   8,   8,  14,  28,  31,  34,  32,  32,  33,  30,
         27,  15,  21,  20,  19,  21,  14,  20,  30,  22,  12],
       [ 17,  12,  14,   7,   3,   8,  18,  20,  10,   1,   4,  16,  10,
         17,  -2,  13,   3,   3,  17,  21,  26,  35,  23,  20,  13,  26,
         37,  24,  24,  20,  13,  16,  15,  12,  11,   5,  19],
       [ 11,  14,   4,   4,   2,  11,  18,  25,  15,   9,   2,   6,   7,
          2,   4,   8,  12,   1,   7,  13,  21,  22,  24,  18,   8,  21,
         31,  36,  39,  28,  36,  33,  33,  22,  22,   2,  -2],
       [  9,   2,   6,   2,  -3,   1,   6,  13,  10,   9,   8,   2,  -4,
        -14,   4,  12,  14,   8,   0,   2,  17,  14,  24,  20,   8,   7,
         17,  25,  24,  15,  33,  34,  28,  27,  33,  21,  20],
       [  7,  14,  16,  11,   6,   7,   4,   6,   7,   9,  15,   1,  -2,
         -3,  -5,   8,   4,   1,   3,   7,  19,  16,  13,  10,   6,   3,
         10,  17,  20,  11,  18,  26,  28,  29,  21,  29,  27],
       [ 11,   6,   8,   9,   6,  -1,   0,  -4,   3,   5,   8,  12,   3,
          1,  -2,  -1,  12,   8,   6,  10,   9,   6,   7,  -4,  -2,   6,
          6,   1,  11,   2,   4,   5,  21,  22,  16,  18,  29],
       [  4,  13,  14,  13,   9,   4,  -6,  -8,  -3,   6,   3,   0,   6,
          2,   5,   8,   5,   8,   1,   3,   7,   1,  17,  13,   1,  -6,
          3,   1,   5,   7,   7,  -1,  10,  13,  19,  15,  18]])
```

APPENDIX C: CORDEX ARRAYS

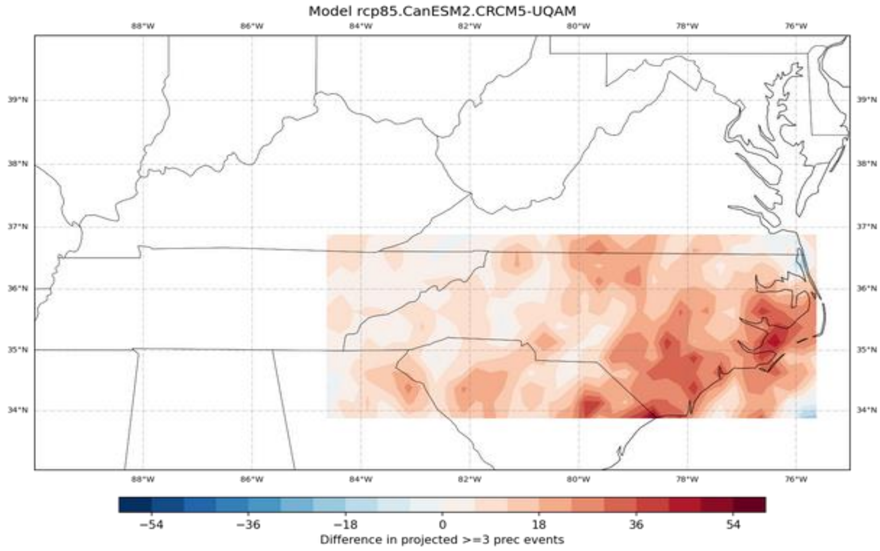
```
Difference in projected >=3 prec events: Model11 rcp85.MPI-ESM-LR.RegCM4 <xarray.DataArray 'prec' (lat: 13, lon: 37)>
array([[  9,   8,   4,   6,  11,  11,   6,   7,   1,  -6,  -5,  -5,   5,
          8,  10,   2,   9,  10,  13,  18,  23,  21,  19,   9,   5,   3,
          7,  -3,   6,   4,   0,   6,  -2,  -1,   0,   8,   5],
       [  9,  15,  12,   6,  -4,   1,   5,  11,   9,  -7,  -5,  -3,  -6,
          0,   1,   7,   2,   6,   9,  16,  10,  19,  15,  17,  16,  18,
         24,   6,   6,   5,   2,   6,  -4,  -7, -18, -10,   4],
       [  6,   0,   9,  10,   4,   0,   3,  10,   2,   3,  -1,  -5,  -1,
          1,  -5,  -1,   4,  -2,   7,  10,   5,   8,   8,  10,  16,  13,
         20,  20,  18,  12,  10,  12,   4,   7, -21, -28, -16],
       [  1,   0,  -3,   5,   1,   1,  -3,   0,  -2,  -1,  -2,  -1,  -1,
          1,   3,  -1,  -6,   3,   2,   9,   7,  11,  15,  14,  20,  17,
         24,  35,  20,  18,  12,  16,  20,  21,   2,  -9, -10],
       [  8,  -1,  -2,   2,   0,  -3,   5,   1,  -3,   2,  -2,   2,   1,
         -2,   0,   5,  -3,  -4,   0,   6,   7,  15,  20,  12,   5,   9,
         17,  25,  20,  19,  19,   7,  12,  23,  14,   3,   0],
       [  8,   5,   8,  -1,  -1,  -3,   4,   4,   3,   4,   0,   4,  -2,
          0,  -2,   1,   2,  -9,  -4,   5,  10,  10,   5,   1,  -2,  -1,
          7,  21,  18,  22,  14,   9,   3,  15,  24,   6,  -2],
       [  2,   3,   2,   5,   2,   4,   1,   4,   0,   4,   0,   4,   5,
         -4,   2,  -1,   5,   1,   1,  -2,   8,   8,  10,   8,   7,   0,
         -1,   7,  16,  12,  11,   9,   5,  18,  10,   9,   4],
       [ 11,  -2,   2,   2,  -1,   2,   3,   1,   3,   5,   2,   5,  11,
          2,   1,   2,   4,   7,   3,  -1,   3,   0,   4,   7,   7,   4,
          4,   7,  10,  12,  11,  15,  22,  18,   9, -15,   1],
       [  5,   5,   5,  -1,   7,   4,   1,  -2,  -1,   3,   3,   6,   3,
          3,  -1,   1,   7,  12,   8,   3,   6,   5,   8,   8,   4,   9,
          8,   7,  12,  15,  10,  12,  24,   8,   1,  -7,  -8],
       [  3,  -4,  -5,   8,   5,   3,   1,  -1,   1,   2,   2,   4,   5,
          1,  -1,  -1,   9,  11,  14,   9,   7,   7,   7,   8,   5,   5,
         14,   7,   5,  13,   7,   7,  14,  10,   7,   6,   1],
       [  3,   0,   1,  -1,   0,   1,  -1,   3,   4,   1,   2,   0,  -1,
         -3,  -5,   0,   0,  10,   7,   2,   3,   8,   5,   5,   4,   6,
         10,   5,   6,   3,   7,   7,  11,   9,  15,   3,  -4],
       [  1,   0,  -3,  -4,  -6,  -7,  -4,   0,  -1,   4,   3,   1,   0,
          3,  -4,  -7,  -3,   2,   0,   3,   2,   3,   5,   9,   5,   0,
          4,   3,   0,   4,   0,  -1,   5,   4,   8,   0,  -1],
       [  4,  -2,  -3,  -2,  -4,  -2,  -6,  -6,  -4,   0,   1,   0,   3,
         -2,  -4,  -1,  -1,  -1,   2,  -1,   0,   4,   5,   3,   6,  -5,
         -5,  -3,   1,   3,   4,   4,  10,   7,   1,   4,  -2]])
```

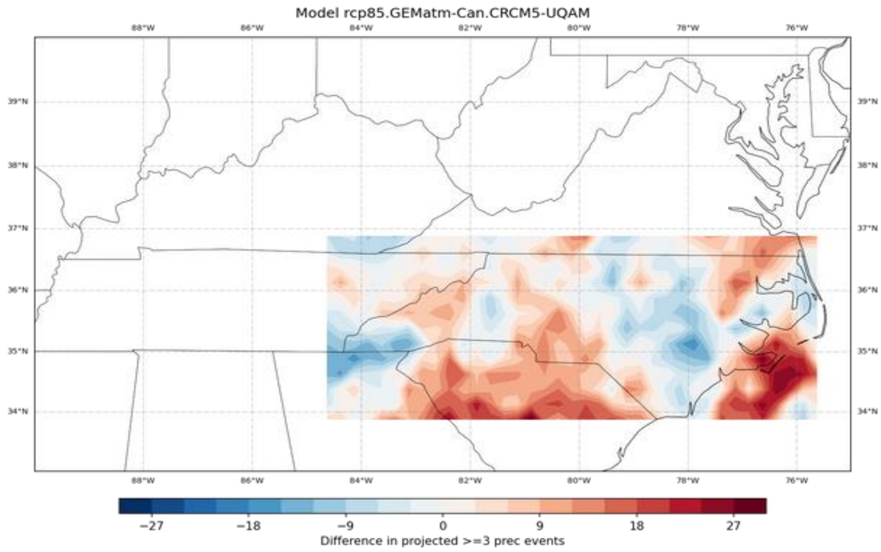
```
Difference in projected >=3 prec events: Model12 rcp85.CanESM2.CRCM5-OUR <xarray.DataArray 'prec' (lat: 13, lon: 37)>
array([[  2,   3,  10,  12,  12,   9,  12,   3,   6,  10,   5,  -8,  -6,
        -10,  -7,  -1,  -9,  -2,  -4,  -9,  -6,  -3, -14, -21, -12, -13,
         -2,  14,  16,   1,   2,  -4,  -5,  14,  20,  18,  21],
       [  2,   9,  14,  13,  16,  11,  12,   3,  -1,   8,  10,   3,  -4,
         -8,  -7,  -7,  -2,  -4,  -3,  -2, -13,  -3,  -6, -20, -20, -15,
         -3,  11,   8,  20,  14,   3,   3,  16,  24,  35,  21],
       [ 12,   9,  11,  16,   9,   9,  12,   5,  11,   6,  12,   1,  -2,
         -6, -13,  -8,   0,  -9, -10,  -3, -10,  -6,  -4,  -8,  -6, -16,
         -6,  -9,  20,  29,  27,   7,   8,  16,  24,  35,  34],
       [  7,   6,  11,   9,  14,  18,   9,   9,  10,  13,   9,   4,  -2,
          0,  -6,  -3,   5,  -5,  -9,  -6,  -7,  -5,   1,  -1,  -6,  -7,
        -10, -10,  -8,  10,  21,   8,  19,  22,  30,  19,  12],
       [  0,   1,   5,  13,  20,  18,   9,  12,  11,   8,  10,   7,   2,
         -1,  -6,  -4,   1,  -3,  -3,  -1,  -5, -10,   2,   2,  -4,  -9,
         -7,  -5, -11,  -1,  -2,   6,  13,  25,  29,  32,  30],
       [  0,  -1,   1,   6,  10,   7,  10,   8,   7,  13,  13,  10,  18,
         11,  -2,  -1,   2,   9,   1,   2,  -2, -10, -11,  -4,  -1,   0,
        -11, -11,  -7,  -2,   4,   1,  20,  21,  16,  19,  19],
       [  2,   3,   6,  10,   4,   6,   9,   3,  11,  19,  13,   3,   8,
          7,   7,   9,   2,   0,   8,   3,   1,  -4,   0,   5,  -1,  -2,
          3,  -4, -13, -24, -12,  -6,  15,  16,  13,  15,  16],
       [  2,  -1,  -1,   3,   5,   4,   8,   7,  11,  10,  18,   8,   4,
          9,  13,  10,   6,   6,   6,   7,   1,  -6,   1,  10,  -2,  -5,
         -5, -15, -20, -18, -14,  -9,  -3,   1,   1,   3,  15],
       [  3,   3,   0,   1,   3,   4,   1,   2,   3,   4,   9,   8,   3,
         11,  16,  17,  15,  11,  12,   7,   5,   1,   4,   4,  -2,  -4,
          6,  -3,  -4,  -5,  -9,  -8, -14,   7,  -3,  -2,   8],
       [  1,   5,   4,   3,   2,   4,   0,   0,   1,   1,   4,   7,  11,
          7,  11,  16,  15,  10,  13,   6,   3,   6,   4,   4,   6,   4,
          2,  -4,   3,   0,  -4,  -1,  -6,  -6,  -2,  -2,   8],
       [  2,   4,   4,   1,  -1,  -3,  -2,  -1,   0,   3,   4,   4,   2,
          6,   7,  10,   9,   5,  18,   7,   2,   3,   5,   5,   0,   4,
          3,   2,  13,  12,   2,   6,   8,   2,  -1,  -1,   3],
       [ -2,   0,   6,   1,  -4,  -3,  -3,  -1,  -4,   0,   0,   3,   3,
          0,   3,   9,   7,   5,  11,   9,   9,  13,  12,   8,   3,  -1,
          3,  15,  17,   8,   1,  -2,  11,   5,   9,   7,   5],
       [  5,   4,   0,   7,   7,   2,   1,   4,   3,   2,   0,   1,   1,
         -2,  -2,   2,   5,  10,  11,  10,   8,  13,  11,   9,  12,  10,
          3,  11,  10,  16,  18,  -2,   8,   8,  12,  14,  17]])
```

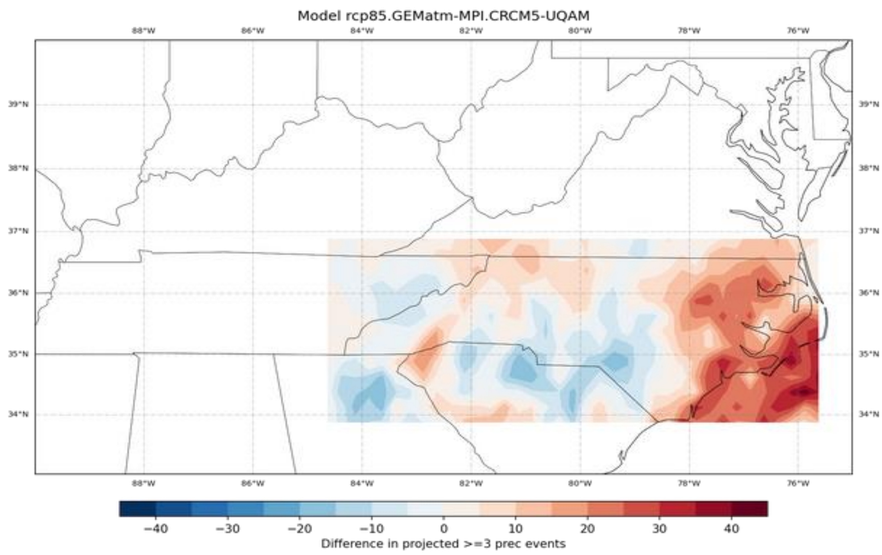
APPENDIX C: CORDEX ARRAYS

```
Difference in projected >=3 prec events: Model13 rcp85.GFDL-ESM2M.RegCM4 <xarray.DataArray 'prec' (lat: 13, lon: 37)>
array([[  0,  -7,   5,   7,   7,   9,   5,   6,   4,   7,   6,   6,   7,
          9,   8,  14,   9,   6,   4,   9,   7,  14,  21,  28,  21,  14,
         10,   9,  11,   6,   6,  11,   6,  -7,  -9,  -6,  -9],
       [ -2,  -5,  -4,   7,  -6,   1,   2,   0,   6,   7,   7,   9,   6,
          5,   1,   9,   5,   6,   3,   9,   5,  -3,   8,  12,  15,  33,
         22,  18,  18,  20,   7,  10,   7,  -3,  -3,  -3,  -5],
       [  4,  -1,  -4,  -1,  -3,   0,  -2,   1,   2,   5,   0,   2,   2,
          3,   4,   3,   4,   6,   6,  -3,   2,  -2,   0,  10,  12,  10,
         12,  20,  24,  29,  19,   8,   8,   3,   1,  -4,  -6],
       [  1,   2,   3,   3,   4,   3,   5,   8,   3,   1,   2,   1,  -2,
          2,   5,   2,   1,   3,   7,   1,   5,   7,   7,   7,  15,   6,
         10,  14,  18,  16,  21,  14,  14,   5,   8,   7,   0],
       [  0,   0,   4,   8,   1,   1,   7,   2,  -6,   4,   2,   3,   1,
         -4,  -5,  -3,   3,   3,   7,   6,   9,   3,   3,   3,  17,  15,
         10,   8,  15,  17,  12,  25,  39,  17,   6,  16,  11],
       [  1,   0,   0,   4,   3,   0,   6,   2,   0,   3,   5,   3,   2,
         -2,  -4,  -3,  -5,  -9,   2,  11,   6,   8,   8,   6,  11,  14,
         12,   8,  18,  12,  22,  28,  22,  17,  14,  11,   9],
       [  4,   2,   5,   5,   0,   0,  -2,  -6,  -3,  -2,   4,   0,   1,
         -1,  -2,  -3,  -3,  -4,  -7,  -1,  10,   5,   5,   7,   7,  14,
         13,  12,  18,  10,  14,  30,  28,   9,  11,  16,   8],
       [  8,   0,   1,   2,   0,  -2,  -5,  -8,  -7,  -2,   1,  -3,  -2,
          0,  -2,  -2,  -3,  -7,  -4,  -3,   7,  11,   3,   2,   1,   9,
         11,  13,  12,  18,   9,  16,  29,  16,   5,  13,  12],
       [  7,   3,   2,   2,   2,   0,  -3,  -4,  -4,   0,   2,   3,   1,
          1,  -5,  -7,  -7,  -7,  -7,  -4,  -1,   5,   2,   2,  -1,   2,
         11,   3,   9,   7,  13,  16,  24,  23,  17,  15,   6],
       [  2,   0,   0,   1,  -1,   0,   2,   1,  -1,  -2,   0,   0,  -1,
         -1,  -1,  -1,  -8, -10, -10,  -4,  -2,  -1,   2,   4,   6,   4,
          4,   2,   0,   0,   4,  14,  16,  13,  26,  18,  -1],
       [  5,   4,   2,   0,  -1,   1,   5,   2,   1,   1,   1,   3,   6,
          5,   5,  -3,  -4,  -5,  -7,  -8,  -2,   3,   1,   3,   2,   6,
          7,   3,   5,   5,   2,   5,  10,   9,  17,  15,  -4],
       [  2,   4,   3,   5,   3,   3,   5,   5,   4,   3,  -1,  -2,   2,
          5,   5,   8,   4,   0,  -1,  -3,  -2,   3,   3,   1,   2,  -2,
          1,   7,   4,   6,   5,   2,   5,  17,  21,  10,  -6],
       [  0,   2,   4,   4,   1,   1,   2,   6,   2,   2,  -1,   0,   0,
          0,   4,   2,   4,   5,   8,   2,  -2,   7,   3,   2,   0,   2,
         -3,   4,   4,   3,   0,   1,   5,  19,  22,   7,   0]])
```

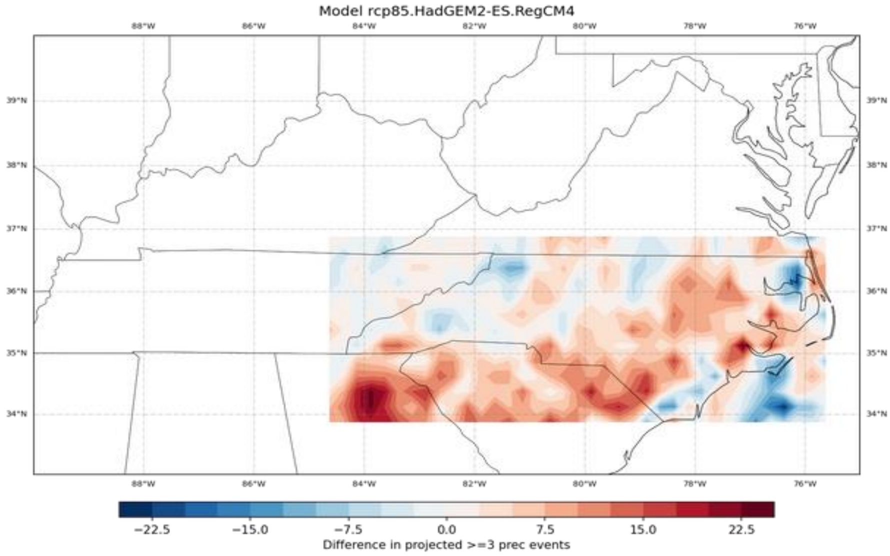
APPENDIX D: CORDEX MODELS

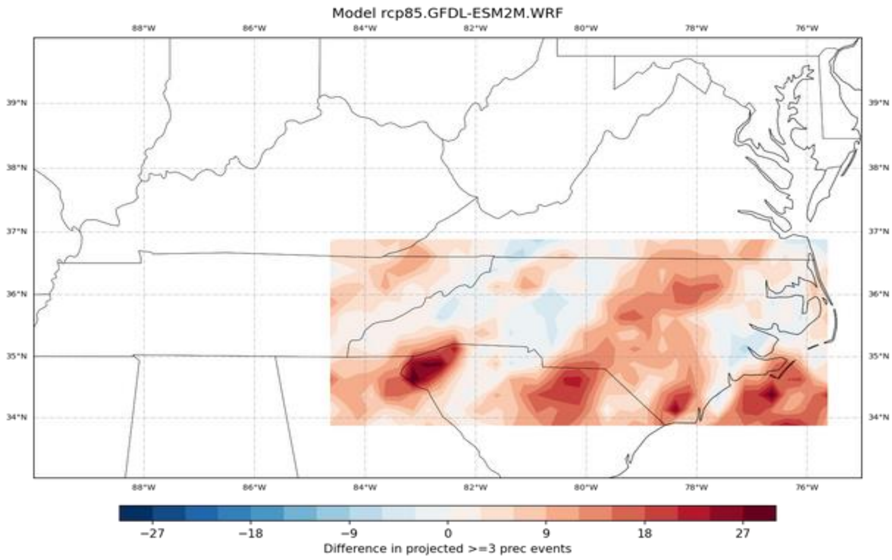


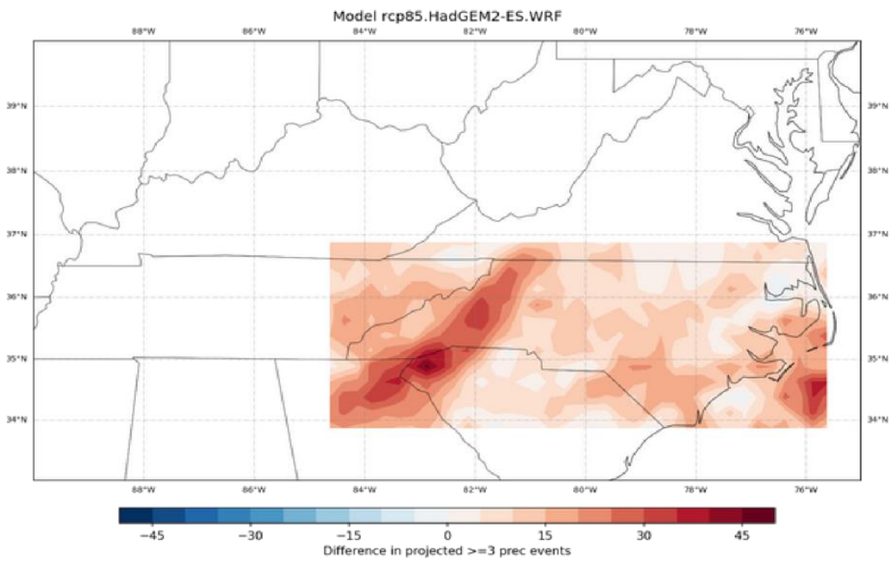




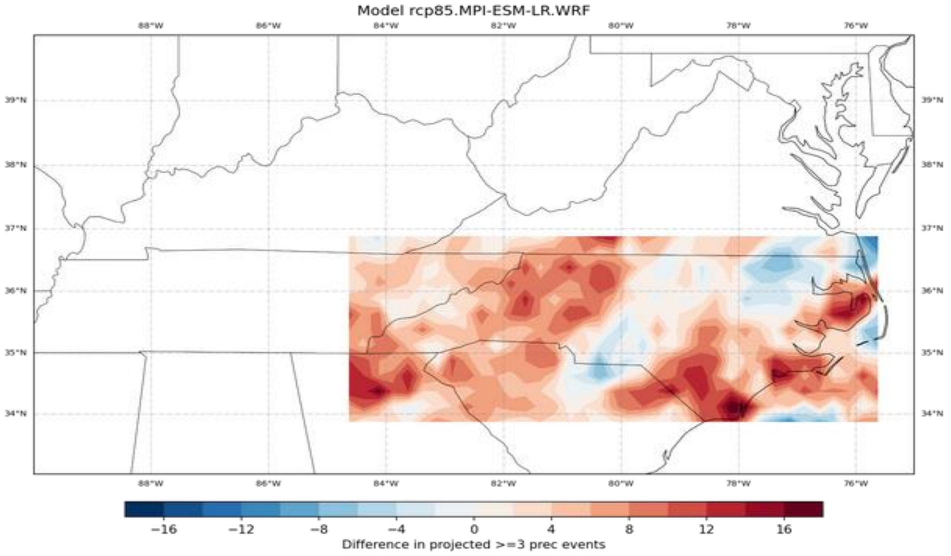
APPENDIX D: CORDEX MODELS

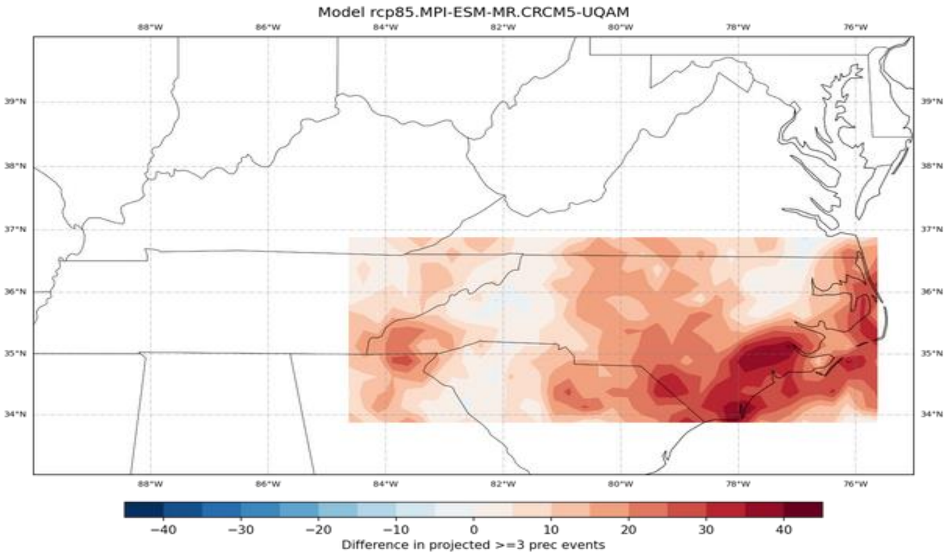


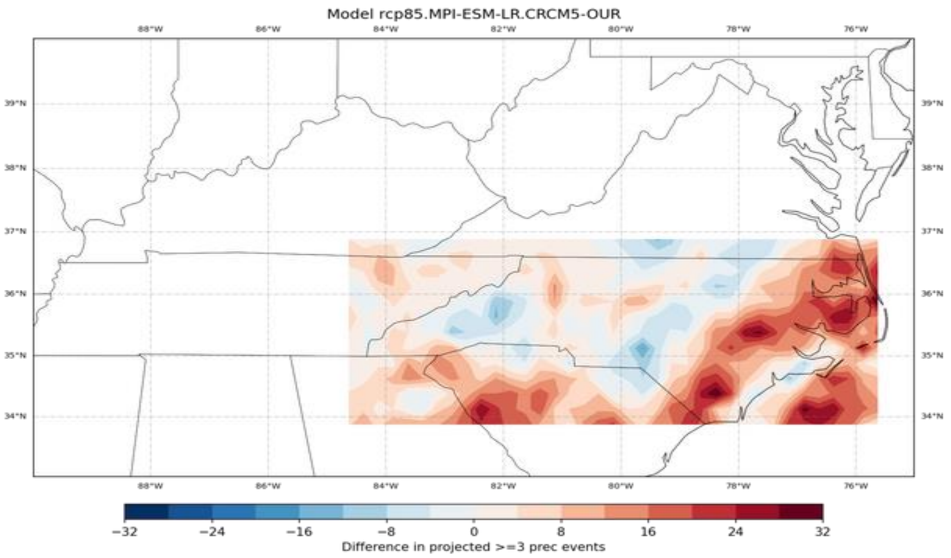




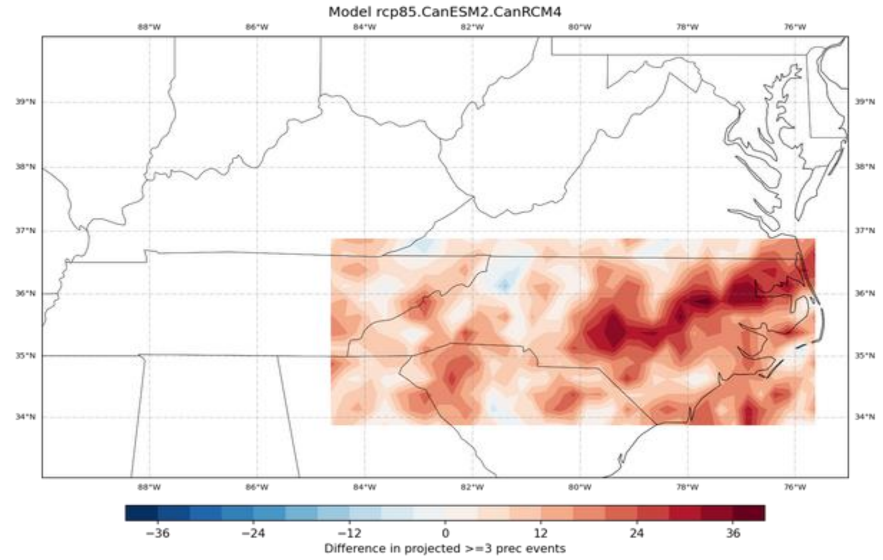
APPENDIX D: CORDEX MODELS

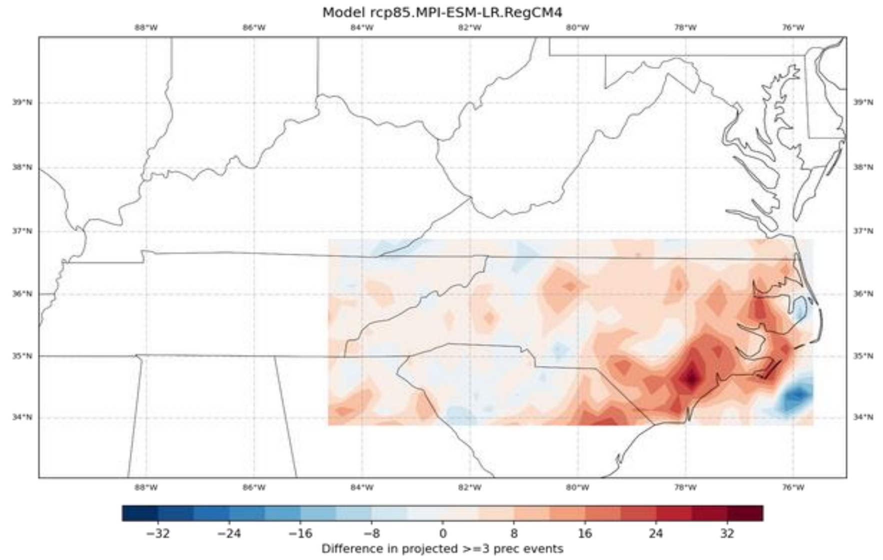


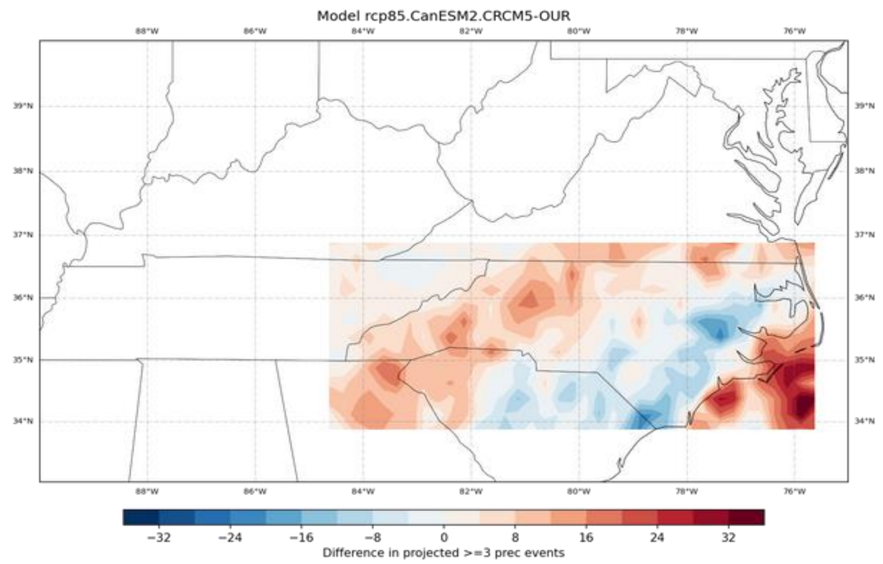




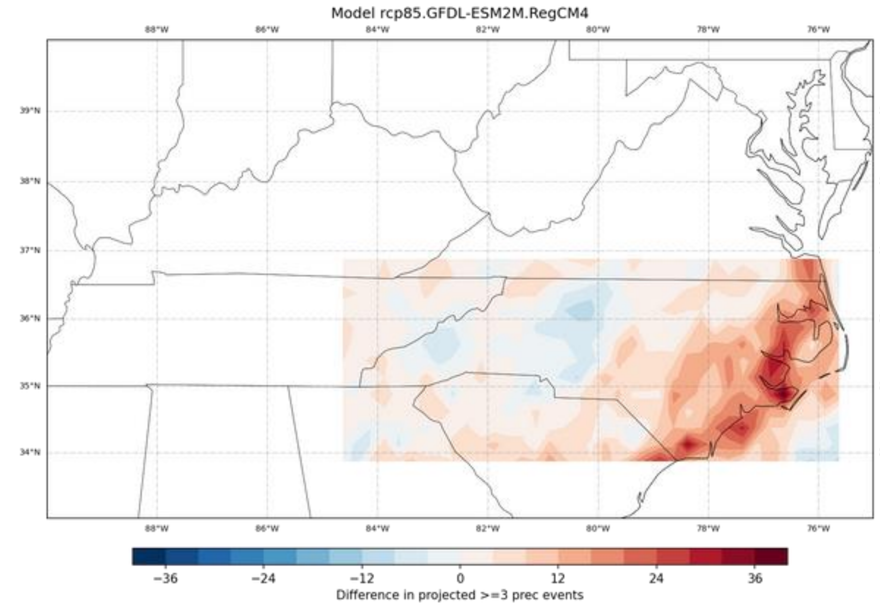
APPENDIX D: CORDEX MODELS







APPENDIX D: CORDEX MODELS



APPENDIX E: PYTHON SCRIPT

GIS

```
#Import libraries

import matplotlib.pyplot as plt
import pandas as pd
import geopandas as gpd
from census import Census
from us import states
import os
```

```
#use API key for census data for 2020

c = Census("4b05a4401ab9ae49c8b3d32cec070a777659a1b5", year=2020)

# Sources: https://api.census.gov/data/2019/acs/acs5/variables.html; https://pypi.org/project/census/

nc_census = c.acs5.state_county_tract(fields = ('NAME', 'C02003_003E', 'B03002_012E', 'C02003_007E', 'C02003_006E', 'C02003_005E
                                      state_fips = states.NC.fips,
                                      county_fips = "*",
                                      tract = "*")
# Create a dataframe from the census data
nc_df = pd.DataFrame(nc_census)

# Show the first two records of the dataframe and how many columns and rows are in it
print(nc_df.head(2))
print('Shape: ', nc_df.shape)
```

```
#shapefile from TIGER projected to UTM 17

# Access shapefile for NC
nc_tract = gpd.read_file("https://www2.census.gov/geo/tiger/TIGER2020/TRACT/tl_2020_37_tract.zip")

#get only county county based on the county number
county_tract = nc_tract[nc_tract['COUNTYFP'] == '001']

# Reproject shapefile to UTM Zone 17N
county_tract = county_tract.to_crs(epsg=32617)
```

```
#join the dataframes so the tracts and the shape match.
#use GEOID

nc_df["GEOID"] = nc_df["state"] + nc_df["county"] + nc_df["tract"]

# Join the attributes of meck tract and nc_df
# Source: https://geopandas.org/docs/user_guide/mergingdata.html
nc_merge = county_tract.merge(nc_df, on = "GEOID")

# Show result
print(nc_merge.head(2))
print('Shape: ', nc_merge.shape)
# Save nc_merge to a shapefile in a folder
nc_merge.to_file(r'C:\User\county_nc_merge.shp')
```

APPENDIX E: PYTHON SCRIPT

GIS

```
import arcpy
from arcpy import env
import os

# set up workspace environment
env.workspace = r"C:\ArcGIS\Projects\buffer_analysis"
env.overwriteOutput = True

# set input and output file paths
flood_zone_fc = os.path.join(env.workspace, r"C:\ArcGIS\Projects\buffer_analysis\FRIS_meck_floodmap\data.gdb\Flood_Hazard_Areas"
census_fc = os.path.join(env.workspace, r"C:\ArcGIS\Projects\buffer_analysis\project.gdb\nc_merge.shp")

# create buffer around flood zones
flood_zone_buffer = os.path.join(env.workspace, "flood_zone_buffer")
arcpy.Buffer_analysis(flood_zone_fc, flood_zone_buffer, "1 Millimeter")

# perform spatial join to get census data within buffer
output_fc = os.path.join(env.workspace, "census_within_flood_buffer")
arcpy.SpatialJoin_analysis(census_fc, flood_zone_buffer, output_fc)

# print count of census features within buffer
count = arcpy.GetCount_management(output_fc)
print("{0} census features found within the flood buffer".format(count))
```

```
import arcpy
import pandas as pd
import matplotlib.pyplot as plt

# Create a dataframe from the census buffer
field_names = ['GEOID', 'NAMELSAD', 'C02003_003', 'B03002_012', 'C02003_007', 'C02003_006', 'C02003_005', 'C02003_004']
df = pd.DataFrame(
    arcpy.da.FeatureClassToNumPyArray(output_fc, field_names),
    columns=field_names
)

# Group the dataframe by flood zone and get the count of each demographic variable
grouped = df.groupby('GEOID')[['C02003_003', 'B03002_012', 'C02003_007', 'C02003_006', 'C02003_005', 'C02003_004']].sum()
```

```
df.to_csv("C:\ArcGIS\Projects\buffer_analysis\floodtracts_county.csv", index=False)
```

```
import pandas as pd
from pandas import read_csv
df=read_csv("floodtracts_{}.csv")

# Plot histograms for each demographic variable by flood zone
for column in df:
    plt.figure()
    plt.hist(df[column], bins=10)
    plt.xlabel(column)
    plt.ylabel('Count')
    plt.title('Histogram of {} by Flood Zone'.format(column))
    plt.savefig("histogram_{}.png".format(column))
    plt.close
```

APPENDIX E: PYTHON SCRIPT

PRISM

```
#import libraries
%pylab inline
import pandas as pd
from pandas import read_csv
%matplotlib inline
import numpy as np
import os
from pandas import read_csv
import matplotlib.pyplot as plt
```

```
co_precip=read_csv('H:\PRISM\precip_county.csv',index_col=0)
co_precip = read_csv('H:\PRISM\precip_county.csv', parse_dates=['Date'], index_col='Date')
# Resample the data to a yearly frequency
yearly_data = col_precip.resample('Y').count()

# Count the number of times that inchesPpt is >= 3 each year
yearly_counts = (col_precip['inchesPpt'] >= 3).resample('Y').sum()

# Group the yearly counts by 20-year intervals
col_vicennial_counts = yearly_counts.groupby(pd.Grouper(freq='20Y')).sum()

# Create a bar chart showing the 10-year counts
fig, ax = plt.subplots()
ax.bar(col_vicennial_counts.index.year, col_vicennial_counts)
ax.set_xlabel('Decade')
ax.set_ylabel('Count of heavy precipitation events')
ax.set_title('Columbus County')
plt.savefig('H:\PRISM\col.png', bbox_inches='tight', dpi=100)
plt.show()
```

```
print(col_vicennial_counts)
```

```
col_inc=((22-14)/14)*100
print('The percent increase in heavy rain events in X County is ' +str(col_inc))
```

APPENDIX E: PYTHON SCRIPT

CORDEX

```
#import libraries
import netCDF4 as nc
from netCDF4 import Dataset
import xarray as xr
import matplotlib.pyplot as plt
import numpy as np

# Load the .nc file
model7 = xr.open_dataset(r'D:\CORDEX DATA\prec.rcp85.MPI-ESM-LR.WRF.day.NAM-22i.raw.nc')
#print(model7)
```

```
# get the difference btwn 30 yrs of nc prec events >=3
# Select the subset of data for North Carolina using latitude and longitude coordinates
precipm7=model7['prec']
nc_prec_m7 = precipm7.sel(lat=slice(33.8, 37.0), lon=slice(-84.7, -75.4))

#GE 3in events
ge_3_m7=(nc_prec_m7 >= 76.2)

# >=3 prec events for the first 30 years
nc_precip_first_30_m7 = ge_3_m7.sel(time=slice('2021-01-01', '2050-01-01')).sum(dim='time')

# >=3 prec events for the last 30 years
nc_precip_last_30_m7 = ge_3_m7.sel(time=slice('2051-01-01', '2080-01-01')).sum(dim='time')

# Calculate the difference in projected >=3 prec events for selected intervals
nc_precip_diff_m7= nc_precip_last_30_m7 - nc_precip_first_30_m7

# Print the results
#print('Difference in projected >=3 prec events: ', nc_precip_diff_m7)
```

```
#make a map for the results

import cartopy.crs as ccrs
import matplotlib.pyplot as plt

def plot_dataset(dataset : xr.Dataset):
    # specify Coordinate Refference System for Map Projection
    projection = ccrs.Mercator()
    # Specify Coordinate Reference System wherethe data should be plotted
    crs = ccrs.PlateCarree()
    # create axes object with a specific projection
    plt.figure(figsize=(16,9), dpi=150)
    ax = plt.axes(projection=projection, frameon=True)
    # draw gridlines in degrees over Mercator map
    gl = ax.gridlines(crs=crs, draw_labels=True,
                      linewidth=.6, color='gray', alpha=0.5, linestyle='-.')
    gl.xlabel_style = {"size" : 7}
    gl.ylabel_style = {"size" : 7}
    # plot borders and coastlines with cartopy features
    import cartopy.feature as cf
    ax.add_feature(cf.COASTLINE.with_scale("50m"), lw=0.5)
    ax.add_feature(cf.BORDERS.with_scale("50m"), lw=0.3)
    ax.add_feature(cf.STATES.with_scale("50m"), lw=0.3)

    #specify extent of the map in minimum/maximum longitude/latitude
    lon_min = -75
    lon_max = -90
    lat_min = 33
    lat_max = 40
    #bring in the data
    cbar_kwargs = {'orientation':'horizontal', 'shrink':0.6, "pad" : .05, 'aspect':40, 'label':'Difference in projected >=3 prec
    nc_precip_diff_m7.plot.contourf(ax=ax, transform=ccrs.PlateCarree(), cbar_kwargs=cbar_kwargs, levels=21)


    ax.set_extent([lon_min, lon_max, lat_min, lat_max], crs=crs)
    plt.title(f"Model rcp85.MPI-ESM-LR.WRF")
    plt.show()



plot_dataset(nc_precip_diff_m7)
```