Equity and Environmental Hazards: Intersections Across the United States and Associated Territories

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Executive Summary

The United States and its associated territories[1] uniquely experience challenges in weather, water, and climate (WWC); *equity, inclusion, and justice* (EIJ); and the intersection of WWC and EIJ, though these issues are not exclusive to any one state or territory and often transcend geographic and political boundaries. Socioeconomic and WWC *vulnerabilities* are inextricably linked, and historically underserved communities are disproportionately impacted by climate and weather hazards.

This study by the American Meteorological Society (AMS) Policy Program aims to 1) identify key challenges and opportunities in weather, water, and climate for the United States and associated territories; 2) assess issues and potential areas for the advancement of equity, inclusion, and justice; and 3) develop a database of challenges and opportunities in WWC and/or EIJ within each respective U.S. state or territory.

Key findings

I. The United States and its associated territories uniquely experience challenges in weather, water, and climate (WWC); equity, inclusion, and justice (EIJ); and the intersection of WWC and EIJ, though these issues are not exclusive to any one state or territory and often transcend geographic and political boundaries.

II. Socioeconomic and WWC vulnerabilities are inextricably linked. Challenges in WWC can exacerbate existing socioeconomic vulnerabilities, and historically underserved communities are disproportionately impacted by climate and weather hazards.

III. The adaptation of communities' social and physical infrastructure is integral to building community resilience, improving public health and human well-being, and avoiding extensive damages and loss of life as a result of challenges in WWC.

IV. There are many intersections of opportunities across WWC and EIJ. Addressing challenges in WWC from a more holistic and interdisciplinary approach can also aid in rectifying issues in EIJ.

V. Given the complexities and interconnectedness of challenges in WWC and EIJ, climate adaptation efforts must be tailored to communities at the local level in order to effectively build community resilience, realize opportunities in WWC and EIJ, and serve all people across the United States and associated territories.

This study synthesizes information solicited from professionals across the WWC enterprise, as well as individuals working in the EIJ space. An extensive literature review, multiple interviews with experts, and historical data on weather and climate from each state/territory has also been incorporated in an effort to provide an accurate representation of the challenges faced across the United States and associated territories. This study and database shall for the foreseeable future exist as living documents, as new insights and information from experts in each state/territory are taken into consideration.

[1] The associated territories of the United States include the U.S. Virgin Islands (St. Thomas, St. Croix, and St. John), Puerto Rico, American Samoa, Guam, and the Northern Mariana Islands.

1. Introduction

The United States and its associated territories uniquely experience challenges in weather, water, and climate (WWC) and *equity, inclusion, and justice* (EIJ), though these issues are not exclusive to any one state or territory and often transcend geographic and political boundaries (Zuzak et al. 2022). There is also a diverse range of opportunities and needs experienced by communities across the United States and territories with respect to WWC and EIJ. Dimensions of societal *vulnerability* and equity in the United States can vary drastically between local communities, and even more so between states and territories (Bullard 1993; Clarke et al. 2023; Mohai et al. 2009). However, all communities need to reduce their vulnerabilities, manage environmental and societal changes, and respond to potential opportunities and risks (Tipton et al. 2022) relating to both WWC and EIJ.

Socioeconomic and climate vulnerabilities are inextricably linked, and historically underserved communities are disproportionately impacted by climate and weather hazards (Lal et al. 2011). Extreme weather events are increasing in frequency and severity around the country, and such events can exacerbate these already existing socioeconomic vulnerabilities. This includes but is not limited to emergency preparedness and response capabilities, reliable and safe *infrastructure* for housing and transportation, and access to education and health services (USGCRP 2023; Gensini and Brooks 2018; Salas et al. 2024; Strader et al. 2019; Seong et al. 2023; Westerling et al. 2006).

The effects of a changing climate—including extreme weather events, variations in temperature, and increased or reduced precipitation—can be observed on the local level. Building societal *resilience* and *mitigating* the compounding effects of climate change may be most impactful with the planning and implementation of initiatives from the bottom-up. Climate change is an issue that, while global in scope and breadth, can be mitigated with solutions at the local level. In order for local and state decision-makers to make the best use of available science and services, there must be an understanding of the challenges faced by their communities with respect to WWC and EIJ (Tripati et al. 2024; Reid 2016; Sung 2013; D'Evelyn et al. 2022; Pallathadka et al. 2021; Kawashima et al. 2000; Zhao et al. 2020; Kleerekoper et al. 2012).

This study by the American Meteorological Society (AMS) Policy Program aims to 1) identify key challenges and opportunities in weather, water, and climate for the United States and associated territories; 2) assess issues and potential areas for the advancement of equity, inclusion, and justice; and 3) develop a database of challenges and opportunities in WWC and/or EIJ within each respective U.S. state or territory.

This study synthesizes information solicited from professionals across the WWC enterprise, as well as individuals working in the EIJ space. An extensive literature review, multiple interviews with experts, and historical data on weather and climate from each state/territory have also been incorporated in an effort to provide an accurate representation of the challenges faced across the United States and associated territories. We intend for this to be a living document as new insights and information from experts in each state and/or territory are taken into consideration.

2. Challenges and Opportunities

The United States and its territories uniquely experience challenges in weather, water, and climate (Pankaj et al. 2011; Zuzak et al. 2022; USGCRP 2023). Identifying challenges and realizing opportunities at the local level can support *community-based adaptation* efforts and building *resilience* from the bottom-up. Given the complexities and interconnectedness of challenges in WWC and EIJ, climate adaptation efforts must be tailored to communities at the local level in order to effectively build community resilience, realize opportunities in WWC and EIJ, and serve all people across the United States and associated territories. (Reid 2016; Tripati et al. 2024; Sung 2013; D'Evelyn et al. 2022; Pallathadka et al. 2021; Kawashima et al. 2000; Zhao et al. 2020; Kleerekoper et al. 2012).

Since 1980, the United States has experienced 396 weather and climate disasters that have exceeded $1 billion, surmounting $2.780 trillion in damage costs. These costly occurrences are increasing in frequency—as of July 2024, 15 extreme weather events have exceeded $1 billion in damages (NOAA/NCEI 2024). However, only considering billion-dollar disasters may not be representative of the full scope of challenges in weather, water, and climate (nor equity, inclusion, and justice) that have been or will be experienced by all communities in the United States and associated territories.

Quantifying the challenges experienced by communities at the intersection of WWC and EIJ is in itself a great challenge. While providing monetary estimates is not the goal of this study, it is important to note some of the limitations of quantifying losses and damages from challenges that transcend between WWC and EIJ.

For example, quantifying the damages of an extreme weather event often focuses on losses of private property and public infrastructure, but may fail to take into account the devastation to the natural environment and the resulting loss of *ecosystem services* (the benefits directly and indirectly provided to humans from the natural environment). The destruction of a forest from a storm can leave a community more susceptible to flooding and exposed to higher temperatures year-round. Even after human-made structures are rebuilt and roadways repaired after a storm, the loss of ecosystems can have persistent and resounding impacts on the surrounding community, leaving new construction more vulnerable to future weather events (Fu et al. 2013; FEMA 2021).

Ecosystem services range from protection against extreme weather to the provision of food and fresh water to the regulation of local and regional temperature. Ecosystems also hold spiritual and cultural value, especially among Native Tribes and Indigenous people. These non-market goods may not directly translate to a monetary value in our current market system. The accurate and inclusive valuation of ecosystem services is a critical component in the future of the weather, water, and climate enterprise, particularly in quantifying damages from extreme weather events (Mooney et al. 2009; USGCRP 2023; Albert et al. 2014).

Another illustration of the difficulty in quantifying the compounding challenges of WWC and EIJ can be seen in the impacts of heatwaves and wildfires in communities that are highly exposed to pollution. Historically marginalized and disadvantaged communities are disproportionately impacted by urban and industrial pollution, resulting in persistent health issues, lower quality of life, and shorter life expectancies. The existing disparities in health due to pollution exposure are uniquely exacerbated by the effects of extreme temperatures and wildfire smoke among disadvantaged communities, with higher rates of heat-related illness, respiratory problems, and mortality (Bullard 1993; Cushing et al. 2015; EPA 2024; D'Evelyn et al. 2022; Li et al. 2022; Hoffman et al. 2020).

Additionally, disaster declarations and federal disaster support activities—such as the allocation of funds for increasing climate resilience in communities—are often reactionary rather than preventative, and are particularly difficult for already disadvantaged communities to obtain. Storm damages in rural areas, for example, often do not result in a declaration of emergency by the state, in part because the costs of damages to mobile homes may not be deemed significant enough to warrant the allocation of state/federal funds for disaster assistance. As a result, disadvantaged communities may not receive funding to aid in their recovery from severe storms, let alone for building resiliency toward the extreme weather events of the future. In contrast, urban areas with permanent residences and/or higher incomes experiencing the same severe storm impacts may yield damage costs that are more likely to trigger a declaration of emergency by the state or federal government.

State and federal assistance programs can be largely inaccessible to marginalized populations, such as Indigenous communities. Limited communication, collaboration, and engagement between state and federal entities with Tribes and Indigenous leadership can lead to a lack of awareness of funding opportunities in the communities that could benefit from them the most. Many state and federal assistance opportunities are also specifically designated for municipalities, presenting difficulties for some Indigenous communities (who may lack a municipal government outside of their own Tribal government) in obtaining funding for disaster assistance. Without representation at the city or county level, some Indigenous communities may be deemed ineligible to apply for financial assistance even after experiencing a disaster (Ristroph 2019; Department of Interior 2020).

Building societal resilience and mitigating the compounding effects of climate change may be most impactful with the planning and implementation of initiatives from the bottom-up. Climate change is an issue that, while global in scope and breadth, can be mitigated with solutions at the local level. Although local policymaking originally perpetuated many of the issues in environmental justice seen today, it now holds solutions in reducing vulnerabilities of historically marginalized communities. In order for local and state decision-makers to make the best use of available science and services, there must be an understanding of the challenges faced by their communities with respect to WWC and EIJ (Lal et al. 2011; Tripati et al. 2024; Reid 2016; Sung 2013; Pallathadka et al. 2021; Zhao et al. 2020; Kleerekoper et al. 2012).

Some of the most prevalent—and costly—challenges in WWC experienced across the United States and its territories include *severe storms*, *extreme temperatures*, *flooding, drought*, *wildfires*, and *ecological disruption* (NOAA/NCEI 2024; Zuzak et al. 2022; Mooney et al. 2009).

- ***Severe storms:*** Severe storms are increasing in frequency and severity, and the upturn of tornado activity presents a great risk for rural and disadvantaged communities that are disproportionately impacted by extreme weather events.
- ***Extreme temperatures:*** Extreme temperatures can have significant impacts on man made systems and the natural environment; exacerbating existing public health issues, straining a region's infrastructure, and disrupting local economies.
- ***Flooding:*** Flooding is being experienced more frequently and drastically across many states and territories. Extreme temperatures, ice and permafrost melt, severe storms, and coastal and riverine erosion can precede or coincide with flood events.
- ***Drought*****:** The increase in the occurrence and persistence of drought can cause widespread agricultural losses (crop and livestock mortalities), impact local economies, amplify issues of food and water security, and pose a great risk to the health and well-being of local communities.
- ***Wildfires*****:** A once cyclical and seasonal occurrence has become a persistent presence and threat. Wildfires have become more frequent and far-reaching, influenced by drier summers with extreme temperatures and incessant droughts, and can devastate communities on a local and regional level.
- ***Ecological disruption:*** Both anthropogenic activities and the compounding challenges in weather, water, and climate pose a great risk to the function and well-being of ecological communities and the provision of ecosystem services.

Challenges in WWC can exacerbate already existing socioeconomic vulnerabilities experienced by communities throughout the United States and territories. Present-day inequalities in exposure to environmental hazards can in part be attributed to historical discriminatory community planning policies, such as segregation and redlining. The history of deliberate discrimination against certain demographics of people (e.g. Black, Latino e, Indigenous, LGBTQ +, immigrant, and/or elderly populations) has had a lasting impact on the unequal burden of environmental hazards experienced by these communities in the present day (Mohai et al. 2009; USGCRP 2023; Ristroph 2019; D'Evelyn et al. 2022; Hoffman et al. 2020; Bates 2013; Li 2021; Wilson 2020).

The following issues in equity, inclusion, and justice that intersect with challenges in weather, water, and climate include but are by no means limited to the following: *exposure to pollution*, *urban heat*, *food and water insecurity*, *disaster preparedness and response*, *housing and community infrastructure*, and *accessibility of education* (Li 2021; Bates 2013; Bronen 2013; Salas et al. 2024; Bullard 1993).

- ***Exposure to pollution***: Historically marginalized and disadvantaged communities are disproportionately impacted by urban and industrial pollution, resulting in persistent health issues, lower quality of life, and shorter life expectancies.
- ***Urban heat***: The burden of urban heat intersects with issues of public health and environmental justice. Marginalized communities are disproportionately affected by extreme temperatures and experience higher rates of heat-related illness and mortality. Urban neighborhoods with higher rates of poverty also experience higher rates of heat-borne illness.
- ***Food and water insecurity***: Access to safe and sustainable sources of food and water is necessary for the health and well-being of individuals and communities at large. Disadvantaged and marginalized communities are more likely to experience food and water insecurities. Warming temperatures and drought can amplify these insecurities.
- ***Disaster preparedness and response***: Disaster declarations, and the allocation of funds for increasing resilience in communities, are often reactionary rather than preventative. Financial assistance for disadvantaged areas may be limited or nonexistent following extreme weather events, as the costs of property damages may not be deemed significant enough to warrant the allocation of state/federal funds for disaster assistance. There may be a lack of capacity and resources for emergency response services in disadvantaged communities, particularly in rural areas.
- ***Housing and community infrastructure***: A history of systemic marginalization of communities has a lingering effect on the present-day reliability, resilience, and adaptive capacity of a community's infrastructure. Disadvantaged communities have higher percentages of individuals experiencing energy insecurity and houselessness.
- ***Accessibility of education***: There is a need for increased access to quality and affordable education opportunities across the United States and territories, especially for rural and disadvantaged communities. Accessibility to quality education can help build community resilience and increase disaster preparedness in local communities that are susceptible to extreme weather events.

Many vulnerabilities in communities exist as a result of—and in tandem with—challenges in WWC and EIJ. Addressing challenges in WWC from a more holistic and interdisciplinary approach—such as by incorporating considerations of ecosystem management, public health, urban development, ecological and social well-being, and Indigenous knowledge, for example—can also aid in rectifying issues of EIJ (Tipton et al. 2022; Reid 2016; Way et al. 2018; Sung 2013; Kawerak 2022; Albert et al. 2014; David-Chaves 2018).

Just as there is extensive overlap between the challenges faced by each state/territory, there is also an intersection of potential opportunities for these communities in both WWC and EIJ.

These opportunities include but are not limited to the following: *renewable energy*, *climate-resilient agriculture*, *adaptation of infrastructure*, *ecosystem conservation, restoration*, *and management, community engagement and education*, and *Indigenous Knowledge and sovereignty* (Clarke et al. 2023; Álvarez-Berríos et al. 2018; Lee 2023; FEMA 2021; Tucker 2001; Ash et al. 2020; D'Evelyn et al. 2022; Tipton 2023; White 2022; Roos et al. 2021; Peralta 2016; Martinez et al. 2024).

- ***Renewable energy:*** Investments in renewable energy can increase the safety and reliability of energy systems in local communities, reduce their exposure to harmful pollutants, and alleviate energy insecurities. Ensuring that the transition to renewable energy is accessible and affordable for all communities is critical.
- ***Climate-resilient agriculture:*** Climate-resilient agricultural practices, such as prioritizing soil health and selecting heat-tolerant crops, can alleviate food insecurity and strengthen local economies. Agriculture is a major economic driver in many states and territories, and building resilience within this industry is essential for these communities' wellbeing.
- ***Adaptation of infrastructure:*** Adaptation o*f physical and social infrastructure* will allow communities to be more healthy, connected, and resilient, especially in the face of an increasingly volatile climate. Increasing community connectivity and availability of resources for rural areas can build resilience at the local level.
- ***Ecosystem conservation, restoration, and management***: A consideration of conservation biology and ecological processes is vital to effective ecosystem conservation, restoration, and management. The implementation of *ecosystem-based (nature-based) solutions* into community planning, development, and adaptation efforts can increase the resilience and adaptive capacity of both ecosystems and local communities. Ecological forecasting presents a unique opportunity to integrate the physical, biological, and ecological sciences.
- ***Community engagement and education***: Education and outreach programs are a key component of extreme weather preparedness and can empower residents to increase their resilience and adaptive capacity at the household, neighborhood, city, county, and state levels. A strong foundation in environmental and climate education for all individuals can empower local leaders to make informed decisions and strengthen the weather, water, and climate workforce from the bottom-up.
- ***Indigenous Knowledge and sovereignty:*** The convergence of western (non-Indigenous) and Indigenous weather, water, and climate sciences presents an opportunity to address the impacts of colonialism on these communities and to acknowledge the value of Indigenous science in and of itself. Indigenous people and Native Tribes having the right to practice and preserve their cultures, and to protect and manage their historic lands, can alleviate both environmental and societal stressors that have for years disproportionately impacted their communities.

3. Overview of States and Territories

This section provides an overview of some of the prevalent challenges in WWC across the United States and territories, and the ways these intersect with issues of equity, inclusion, and justice in six states or territories. Please consider the following: 1) this list is by no means exhaustive; 2) there are many compounding issues experienced by states and territories, with regards to both WWC and EIJ, and so the consideration of some challenges will require the consideration of another (e.g., flooding and sea level rise, and/or drought and wildfires); 3) though each community uniquely experiences challenges in WWC and EIJ, the issues described here are not exclusive to any one state/territory—these issues often transcend geographic and political boundaries and are experienced by many differing communities.

3.1 Severe Storms

Alabama

Severe storms present an immense threat to both people and property. Strong winds damage power lines and cause widespread outages. Heavy precipitation floods roadways and homes. Lightning strikes cause fires, electrical damages, and sometimes fatalities. Hail can impair and injure drivers and result in deadly car accidents.

Severe storms have historically yielded high levels of damage and loss of life in Alabama (Agee and Taylor 2019). In 2024 alone, severe storm events have surmounted $13.4 billion in damage costs for the state of Alabama (NOAA/NCEI 2024). Tornado Alley, a geographic region with frequent tornado occurrences in the central United States, has gradually been shifting eastward across the country. The upturn of tornado activity throughout the Southeastern United States and the increase in frequency of severe storms presents a great risk for the future of the region (Gensini and Brooks 2018; Moore and DeBoer 2019). The impacts of severe storms, and tornados in particular, on communities in the state of Alabama is a paragon of the intersection of challenges in weather, water, and climate, and equity, inclusion, and justice. There is a need for increased emergency preparedness, response, and education opportunities, with a particular focus on rural and disadvantaged communities and severe storms (Strader et al. 2019; Ash et al. 2020).

Alabama has one of the highest percentages of people in poverty in the United States (U.S. Census, 2024). The state and local government(s), especially in rural areas, can be limited in their capacity to provide basic services to citizens, including access to education, critical infrastructure, and emergency management, communication, and response systems. Mobile home residents, for example, have higher vulnerability (both physically and socioeconomically) to tornados than residents in permanent home structures, in part due to the greater distances required to travel to tornado shelters compared to those residing in more densely populated communities (Chaney et al. 2013).

A supercell thunderstorm captured by Michael Coniglio, NOAA

There are limitations in the ability of rural communities to obtain financial assistance from the federal and state government(s). Severe storm damages in rural areas often do not result in a declaration of emergency by the state, in part because the costs of damages to mobile homes may not be deemed significant enough to warrant the allocation of state/federal funds for disaster assistance. As a result, disadvantaged communities may not receive any funding to aid in their recovery from severe storms, let alone for building resilience toward extreme weather events of the future. In contrast, urban areas with permanent residences and/or higher incomes experiencing the same severe storm impacts may yield damage costs that are more likely to trigger a declaration of emergency by the state or federal government.

"We're finding that these tornado-vulnerable, low income communities do not receive the state and federal assistance they need for disaster recovery. [For example], in March of 2023, the primarily Black and impoverished community of Camp Hill, Alabama endured tornadoes, flooding, AND hail within three days. Even though a majority of the mobile homes and low income housing of the town was destroyed, the cost of the disaster did not trigger a state declaration of emergency."

– Abigail Franks, Southeast Climate and Energy Network

Increasing accessibility of state and federal funding for rural communities, such as through technical assistance grants and rural partnership programs, can build community resilience. The U.S. Department of Agriculture (USDA)'s Rural Development programs, for example, have grant and technical assistance opportunities available to improve the well-being of communities in the rural United States, such as by supporting efforts toward improved disaster preparedness, resilience, and recovery. Additionally, a grant from the USDA's National Institute of Food and Agriculture (NIFA) made it possible for the University of Auburn to establish an Institute for Rural Partnership (Rural Partnership Institute 2024). This project aims to research and remedy challenges faced by rural communities in Alabama, including mitigating pollution in waterways and advancing the economy of the agricultural sector and rural Alabama overall. A more robust and developed local economy can increase a community's overall well-being and reduce vulnerabilities.

There is an opportunity to build resilience and avoid loss of life through increased capacity for education and communication of extreme weather events, household preparedness, and emergency response at the local level. Although tornado forecasting, prediction, and communication capabilities have improved in recent years, residents in areas with frequent tornado activity should be prepared to respond to tornado warnings with zero (as the tornado is forming) or negative (after the formation) lead time to avoid injury and loss of life (Brotzge and Erickson 2009). Gaps in radar coverage in rural and disadvantaged communities may also hinder their ability to be adequately informed and prepared for an impending storm. Improvements to tornado prediction, detection, and warning operations and filling in gaps in radar coverage can provide residents with the time they need to effectively prepare for a disaster (Simmons and Sutter 2008).

Household preparedness can be influenced by the individuals' knowledge of the extreme weather event, their perception of the risk, and their source(s) of information about severe storms (such as from their local news station, from their neighbors, or, e.g., directly from the National Weather Service; National Weather Service 2023). Having credible communicators that are truly representative of the communities they are working with can increase the effectiveness of education and outreach regarding extreme weather events and climate change impacts. Establishing trust when working with local communities is paramount. There need to be more individuals that are actually from these communities working in weather, water, and climate spaces so that all people can benefit from our science and services, even and especially on the hyperlocal level.

Sources

3.2 Extreme temperatures

Texas

Heatwaves are intensifying in frequency, intensity, and duration. Extreme temperatures can have significant impacts on ecological, biological, and geochemical systems; expediting blooming seasons, causing shifts in the geographic ranges of various flora and fauna, influencing the vitality and reproductive capability of certain species, and altering rates of transpiration and precipitation (Mitchell and Janzen 2010; Pearson 2019). Extreme heat and cold alike pose major risks to human-made systems and can put immense pressure on a community's infrastructure.

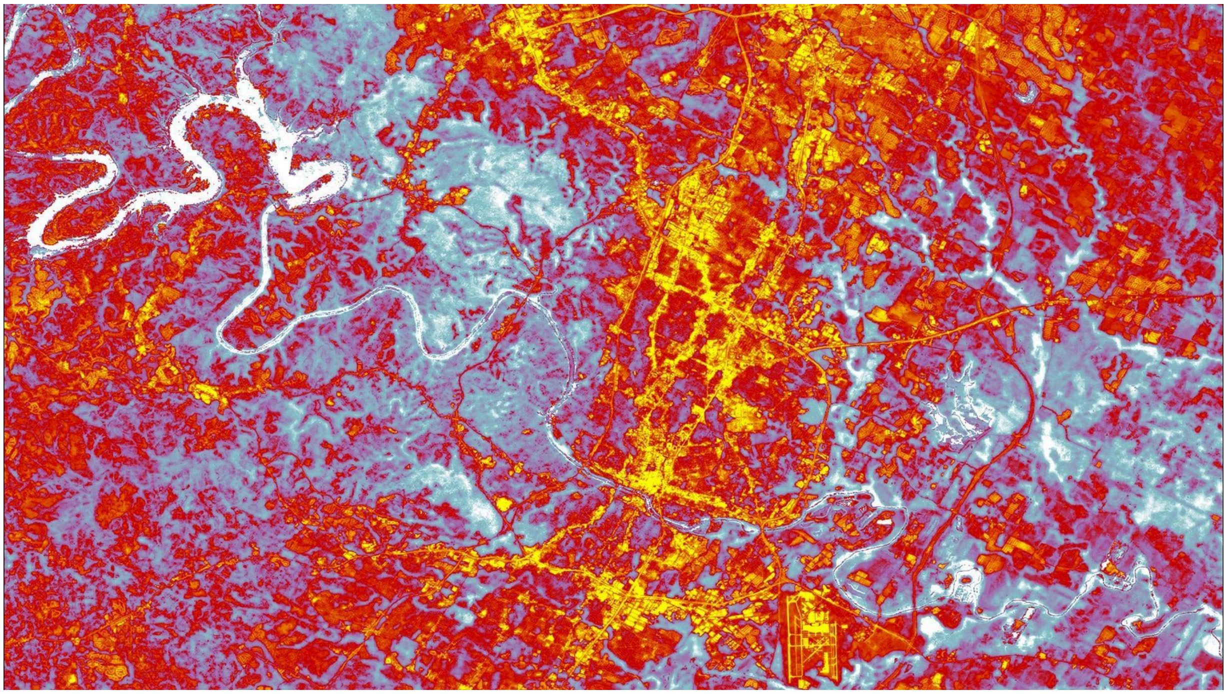
Heat is the leading cause of weather-related deaths globally (NASA 2024). Marginalized communities are disproportionately affected by extreme temperatures and experience higher rates of heat-related illness and mortality. The challenge of *urban heat islands*—concentrations of higher air and surface temperatures in urban areas—intersects with issues of public health and environmental justice. Present-day inequalities in urban heat exposure can be attributed in part to historical discriminatory community planning policies, such as segregation and redlining. The deliberate discrimination against certain demographics (e.g. Black, Latino/e, Indigenous, LGBTQ+, immigrant, and/or elderly populations) has had a lasting impact on the unequal distribution of heat exposure and heat-related illness within cities (Wilson 2020; Hoffman et al. 2020; Li et al. 2022; Seong et al. 2023).

The state of Texas is experiencing increasing urban heat island effects throughout its cities due to tremendous urban development, population growth, and a resulting decline in green spaces and vegetation. The population of Texas has increased by over 43% since 2000, exceeding 30 million people in 2022 (Wilder 2023). Land-use changes as a result of population growth—deforestation, industrialization, and urbanization—have a major influence on average temperatures locally and regionally (Streutker 2003; Darby and Senff 2007; Deng et al. 2013).

Sudden increases in electricity demand during heatwaves and cold spells can strain a region's energy grid. The severity of impacts extreme temperatures have on a community's infrastructure largely depends on how long the temperatures persist. Severe winter storms and resulting cold snaps, such as observed in Texas in February 2021, can leave millions of residents without electricity, running water, and heat for days due to compounding failures of community infrastructure, including electricity generation and water systems. These sudden freezes have caused loss of life, damage to critical infrastructure, and widespread agricultural mortalities. The freezing temperatures of the February 2021 winter storm prompted unprecedented stress on Texas's energy grid and shone light on the vulnerability of the state's critical infrastructure. These vulnerabilities were highlighted once again in July 2024 in the aftermath of Hurricane Beryl when widespread power outages left nearly 3 million people exposed to extreme heat in the days after the storm. (Doss-Gollin, J. et al. 2021; Leslie 2021; Salhotra et al. 2024).

Local and regional decision-makers must incorporate a consideration of increasingly volatile temperatures in their community planning and development processes, as well as a consideration of equity with which residents will be disproportionately exposed to heatwaves and freezes. Although local policy-making originally perpetuated many issues of environmental injustice seen today, it now holds solutions in reducing vulnerabilities of historically marginalized communities and combating urban heat (Kleerekoper et al. 2012; Sung 2013; Zhao et al. 2020).

An area known as the "Eastern Crescent" in Austin, TX Texas, has some of the highest rates of poverty in the city and also experiences higher heat vulnerability compared to surrounding areas (Seong et al. 2023). The residents in these neighborhoods (primarily Black and Latino/e) are not only at risk of rising temperatures, but of rising housing prices, *gentrification*, and displacement. Increased investments, adaptation efforts, and new local policies aimed at alleviating disparities in areas such as the Eastern Crescent should not exacerbate the threats of displacement that these communities face (Way et al. 2018).



Mapping of urban heat distribution in Austin, Texas by NASA DEVELOP

Investments in adaptation are necessary to accommodate Texas's growing population and the resulting increase in energy demand to stay cool during sweltering summers and to stay warm in sudden cold snaps. Concrete is more conducive to increasing urban heat island effects than trees and shrubs; incorporating urban tree canopies in landscape planning can lessen the intensity of urban heat islands and mitigate extreme temperatures during the summer months. Increasing accessibility and availability of cooling centers in underserved communities can help prevent heat-induced illness and mortality. Adapting critical infrastructure to accommodate growing energy demands, especially during severe storms, heatwaves, and cold snaps, can also avoid loss of life. Inequalities related to extreme temperature (i.e., exposure, adaptive capacity, and related illnesses) must be taken into account in the development of hazard mitigation programs and urban planning.

It is essential that local and regional decision-makers tailor their efforts and policies to address the effects of extreme temperatures to specific community needs, including the socioeconomic dimensions and the physical and social infrastructure(s) of their neighborhoods. Urban heat mapping initiatives [e.g., such as the collaborative efforts between the National Integrated Heat Health Information System (NIHHIS) and NASA's Applied Remote Sensing Training Program (ARSET)] can provide local decision-makers with the information needed to best adapt their communities to extreme temperatures, reduce geographic inequities in heat exposure, and lower instances of heat-related illness in at-risk communities.

Sources

3.3 Flooding

Alaska

The arctic is warming at a higher rate than anywhere else in the United States. This "arctic amplification" and the distinct climatic, geographic, socioeconomic, and political dimensions of the arctic region present a need for unique approaches to the challenges faced by its communities (Miller 2021; Rantanen et al. 2022). Alaska experiences numerous challenges in WWC and EIJ—with flooding intersecting both areas of focus (Bronen 2013; Gudmestad 2020). Extreme temperatures, permafrost melt, decreasing sea ice cover, severe storms, and coastal and riverine erosion can precede or coincide with flood events.

Both coastal and inland communities are vulnerable to flood risks as a result of thawing permafrost, melting ice, and erosion (Lee 2023). Permafrost is one of the largest terrestrial carbon sinks, and rising temperatures are causing this frozen sediment to thaw, releasing greenhouse gases into the atmosphere, impacting river runoff, soil health, and freshwater reservoirs (NOAA 2021). The melting of permafrost has widespread impacts on both the natural and human-made environments in Alaska, in part by contributing to erosion and damaging the critical infrastructure of communities. While permafrost melt can catalyze flood events, flooding itself has the potential to increase soil temperatures and thaw permafrost further. The warmer temperatures of floodwater also make sediment more susceptible to erosion, which can further exacerbate flooding. Warming temperatures and shifts in seasonality are also making the breakup of river ice harder to predict, and heavy precipitation, ice melt, and break up can cause devastating floods in riverine communities. Permafrost melt and land erosion affect communities in tandem—both influence and are influenced by flood events (Zhang et al. 2023; Wang et al. 2023; USDA Climate Hubs 2024).

Alaska Native Villages (ANVs) are especially and increasingly vulnerable to flooding (Marino 2015). Indigenous (American Indian and Alaska Native) people compose 15% of Alaska's population and are disproportionately impacted by climate hazards (U.S. Census 2023). The majority of communities are located in extremely rural areas, face high levels of poverty, and have limited access to critical infrastructure, education, or reliable transportation. Many communities experience food, water, and energy insecurities. As European colonizers moved into Alaska during the 18th and 19th century, Indigenous communities were displaced and forced to relocate to areas of higher risk. Alaska Natives settled along shorelines susceptible to coastal erosion and low-lying lands in the floodplains. While ANVs along the coasts experience the compounding effects of sea level rise, coastal erosion, and coastal inundation, Native Villages farther inland are also vulnerable to flooding to riverine flooding events and erosion of the riverbanks. The remote location of ANVs and the increasing volatility of weather and climate throughout the arctic region continues to exacerbate the existing vulnerabilities of these communities (Tribal Climate Resilience Program 2020; Kawerak 2022)

There are multiple barriers to advancing flooding adaptation and mitigation for Alaska Native Villages (Ristroph 2019). With many state and federal assistance opportunities being specifically designated for municipalities, this poses a great difficulty for Indigenous people to obtain funding for disaster assistance. Many ANVs lack a municipal government outside of their own tribal government, making some communities ineligible to apply for financial assistance even after a disaster. Additionally, disaster declarations and funding opportunities are often reactionary rather than preventative. A major flood event may warrant a disaster declaration, but worsening coastal or riverine erosion that exacerbates the impacts of flooding may not. Indigenous people are currently underrepresented in both science and policy in the arctic, and have historically been excluded from local and regional decision-making processes. Hazard mitigation plans, for example, have sometimes been developed for ANVs without inclusion of Indigenous voices and therefore do not accurately reflect the challenges and needs of their communities.

Melting permafrost (and the resulting exposure of minerals and metals) may be the cause of the discolored waterways in Gates of the Arctic National Park and Preserve.
Photo by Ken Hill, National Park Service.

Non-Indigenous people working in science, policy, and disaster mitigation and response must consider their intent versus impact when working with Indigenous communities. Historically, the scientific community has engaged with Indigenous people in a way that has been exploitative and continues to perpetuate colonialism, even if the work itself was initially intended to benefit those same communities.

There is a need for an increase in collaboration with Indigenous communities and improved accessibility of funding opportunities for flooding adaptation and mitigation. In some cases, such as for the Native Villages of Kivalina and Newtok, there is a need for adequate assistance and consideration of *managed retreat* or *coastal realignment* (the voluntary and coordinated relocation of communities away from areas of high risk) as a viable option for improving community resiliency and avoiding loss of life (White 2022). To plan and implement effective and inclusive flood mitigation and response practices, it is essential to evaluate the flood risk utilizing both scientific observations and local Indigenous knowledge.

Scientific observations in the arctic are limited in capability and expensive in cost; there is a need for an increase in scientific observations and infrastructure. There must be intentional inclusion and purposeful participation of existing Alaskan Native Villages and Indigenous people in order for the state of Alaska to better predict, monitor, and respond to flood events, inform decision-making, and improve flood management practices.

Sources

3.4 Drought

U.S. Caribbean

Drought events are influenced by many environmental factors; precipitation levels, temperature, humidity, and winds can all induce drought conditions. Reduced precipitation over an extended period of time, as well as higher temperatures, lower humidity, and high winds can contribute to the onset of drought. Droughts can persist in a region over various periods of time, from weeks to months to years, and can be extremely costly. The ecological and socioeconomic impacts of drought are widespread and are experienced uniquely within different communities (Mishra and Singh 2010).

Rapid drought poses a significant challenge for Puerto Rico and the U.S. Virgin Islands (comprising the islands of St. Thomas, St. Croix, and St. John). Despite frequent rainfall, the tropical climatic zone is particularly susceptible to rapid drought events. With rising temperatures and changing precipitation patterns, drought events are increasing in frequency and intensity across the islands and can be extremely disruptive to their already vulnerable local economies. Communities in the U.S. Caribbean face challenges that are unique to their respective islands (Álvarez-Berríos et al. 2018; Ramseyer and Miller 2023).

There are compounding and intersecting cultural, ecological, and socioeconomic issues experienced by communities in Puerto Rico and the U.S. Virgin Islands (U.S.V.I.) as a result of an ongoing and complex history of slavery and colonial rule. The enslavement of African and Indigenous Taíno people transformed the culture and society in these islands and continues to affect the quality of life and institutions in the present-day U.S. Caribbean. The lingering effects of systemic oppression and settler colonialism in the U.S.V.I. and Puerto Rico can be observed in the region's extremely vulnerable critical infrastructure (including food and water security, transportation, energy, education, and other human services) and in the limited capacity of local governments to respond to extreme weather conditions, such as changes in precipitation, extreme heat, drought, and intensifying hurricanes (Peralta 2016; Kwasinski et al. 2019).

The majority of agricultural practices throughout the U.S. Caribbean are small-scale farms dependent on rainfall and stored rainwater for irrigation. Extreme temperatures and reduced precipitation can inhibit the ability of soil to store moisture, increase rates of *evapotranspiration* (the loss of water from both the crops themselves and the soil), and cause widespread declines in crop yields. Drought conditions can also increase livestock mortality, and limited water availability poses a great risk to the health and well-being of local communities. Water and food security are already at risk throughout the U.S. Caribbean, in part because of the remoteness of these islands and historically having limited access to federal funding opportunities compared to communities in the continental United States. The destabilizing effects of drought on agricultural communities in this region can decrease these communities' independence, heighten food and water insecurities, and increase reliance on imported food and water to sustain their livelihoods (David-Chavez 2018; Holupchinski et al. 2018).

The implementation of responsible water management practices could aid in the prevention of agricultural losses, especially in areas that are entirely dependent on rainfed irrigation systems. Climate adaptive agricultural practices, such as prioritizing soil health, planting cover crops, and selecting heat-tolerant and drought-resistant crops, increases the potential of the soil to retain moisture during the rapid onset of drought and reduces overall crop mortality.

A
A setting sun over the island of Saint Thomas, U.S. Virgin Islands. Photo by Isabella Herrera

Historically, scientific observations have been limited in the U.S. Caribbean region, and an increase in funding for basic scientific infrastructure could aid in providing actionable information for local decision-makers to increase climate adaptation efforts, including improving drought resilience. Predicting drought on a subseasonal time scale, identifying the drivers of flash droughts, and developing more accurate early warning systems could increase resilience to drought within U.S. Caribbean communities. Additionally, the engagement and collaboration with local people, such as through citizen scientist observations, can provide information needed on the hyper-local level to address the challenges presented by drought. Cross-sectoral collaboration, such as through the U.S. Department of Agriculture's Caribbean Drought Learning Network, can bring together local and regional stakeholders to share information, resources, and adaptation strategies to better combat the increasing issue of drought (Mercado-Díaz et al. 2023).

Sources

3.5 Wildfires

California

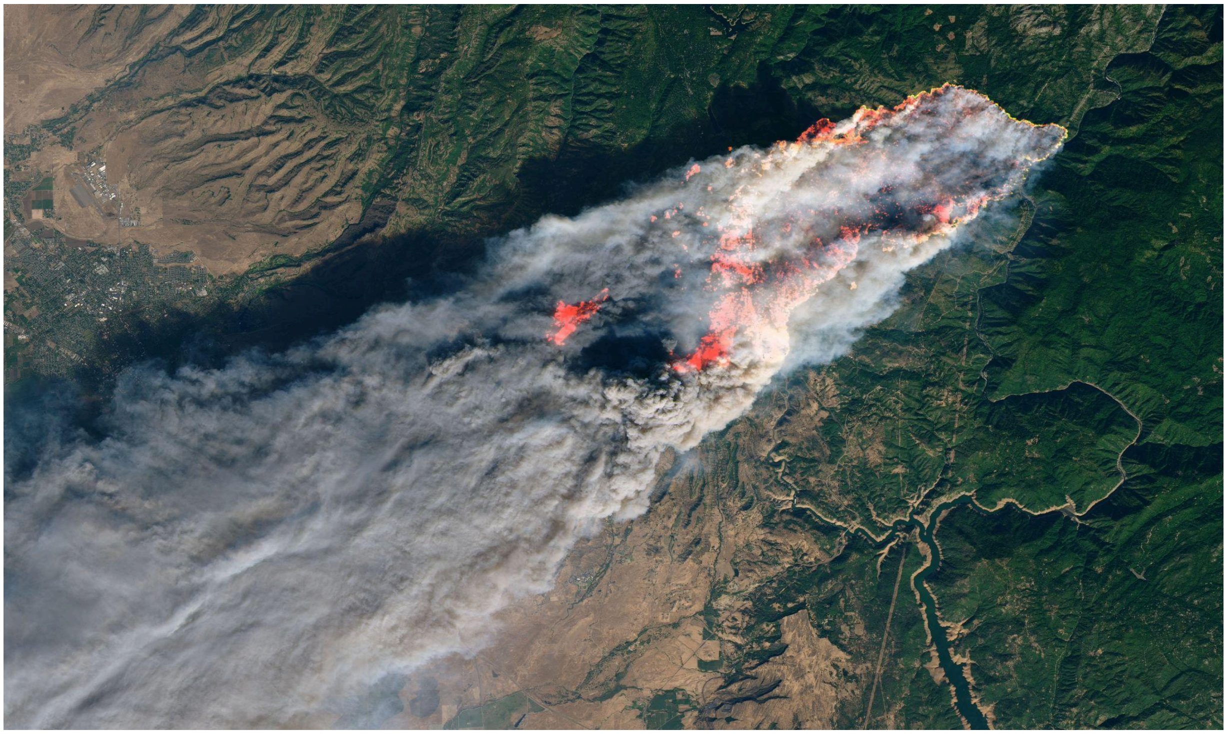
Wildfires are a naturally occurring phenomenon in many terrestrial ecosystems, supporting forest health with the promotion of new tree and shrub growth and maintaining *biodiversity* across landscapes. What was once a cyclical and seasonal occurrence has become a persistent presence and threat. Wildfires have become more frequent and far-reaching, influenced by drier summers with extreme temperatures and incessant droughts, and can devastate communities on a local and regional level (Westerling et al. 2006; Westerling and Bryant 2008).

Like other challenges in WWC, wildfires transcend geographic and political boundaries, and can leave a lasting mark in places where physical flames may never touch. Damages to local water supplies can remain for years after fires have been extinguished. Massive quantities of smoke, air pollutants, and greenhouse gases emitted from wildfires can travel hundreds of miles from the fire itself. Exposure to wildfire smoke can exacerbate existing health problems and disproportionately impact disadvantaged communities. Thus, wildfires of increasing severity have serious implications for ecosystems, the economy, public health, and environmental justice.

The majority of wildfires in the southwestern United States burn across the *wildland-urban interface* (WUI): the area of intersection between wildlands and densely populated urban developments. Communities in the state of California, many of which are located in and along WUIs, are extremely vulnerable to wildfires and are economically, geographically, and culturally diverse from one another. Climate adaptation and wildfire management efforts must be uniquely tailored to communities at the local level in order to effectively serve these communities (Chen et al. 2022).

Forest management, and specifically prescribed burns, are not a new revelation. Years before European colonizers entered North America's wildland landscapes, Indigenous people had managed these forests, prescribing burns to increase agricultural productivity and maintain game populations. Fire suppression results in the accumulation of *fuels*—dry vegetation that can catalyze catastrophic wildfires in forests and shrublands—but regularly prescribed burns aid in preventing such events. As Indigenous people were displaced by European settlements, controlled fire activities declined and fire suppression efforts increased, and over the following century the density of both fuel reservoirs and urban developments in fire-prone areas grew tremendously (Taylor et al. 2016; The Nature Conservancy 2021; Roos et al. 2021).

Wildfires are expensive events; damages resulting from wildfires cost the state and the federal government tens of thousands to billions of dollars each year. California's dense population and expansion of developments into areas of frequent fire activity have resulted in devastating losses of life and property. A community's critical infrastructure—electricity, water supply, and transportation—can experience prolonged impacts long after a fire has run its course. Water resource management is a significant challenge in the state of California, and intersects with issues presented by increasing wildfire activity. Wildfires can pollute water sources, further exacerbate drought conditions, and lead to more frequent flooding in burned lands. Challenges in water resource, fire, and forest management often overlap; while the effective management of source watersheds can reduce fire risk, declines in water supply can lead to an increased likelihood of drought and fire weather conditions. Developing sustainable groundwater management plans and building resilience across state watersheds can aid communities in meeting their needs and better managing wildfire risks (Keeley et al. 2009; Crowley et al. 2023; California Department of Water Resources 2023).



Aerial view of a large fire. Image by Joshua Stevens, NASA Earth Observatory, using Landsat data from USGS

In addition to pollution of local and regional water supplies, there are other prolonged effects of wildfires on human health and well-being, especially in communities that are already exposed to and affected by pollution. Wildfire smoke can exacerbate existing health disparities in vulnerable communities. Over 40% of California's population is Hispanic and/or Latino/e, and these communities are disproportionately impacted by urban and industrial pollution (U.S. Census Bureau, 2024). Reducing vulnerable populations' exposure to wildfire smoke can be fueled by policy changes and community adaptations, including but not limited to the following: increasing health and safety regulations for outdoor workers, establishing community shelters, implementing requirements for new construction to create fire-resistant homes, and ensuring that evacuation information and evacuation routes are accessible (Cushing et al. 2015; D'Evelyn et al. 2022; EPA 2024; Department of Industrial Relations 2024).

Over 43% of households in California primarily speak languages other than English (U.S. Census Bureau, 2024). Providing science and environmental hazard communication resources in other languages frequently spoken in the state (e.g., Spanish and Chinese) can help avoid injury and loss of life. Effective risk communication can and should inspire proactive behavioral change, from refraining from outdoor grilling during *Fire Weather Watches* and *Red Flag Warnings* to knowing when an evacuation order has been issued. Education and outreach programs are a key component of wildfire preparedness and can empower residents to reduce the likelihood of these events and increase their resiliency at the household, neighborhood, city, county, and state levels.

Regular risk assessments can aid communities in identifying vulnerabilities and allow for better prioritization of mitigation and adaptation efforts. Prescribed burns and reducing fuel reservoirs in WUIs can play a major role in mitigating wildfire risk and effective forest management. The monitoring and management of WUIs and other fire-prone areas can further support efforts in fire weather forecasting and preparing local emergency responders for wildfire events. Advancing wildfire response capabilities, such as by deploying Incident Meteorologists (IMETs) to assist firefighters on the ground, can prevent catastrophic fires from spreading and provide information that can help prepare communities to respond to future fires. Addressing the burning issue of wildfire forecasting and detection, management, and response from a more holistic and interdisciplinary approach—incorporating considerations of public health, environmental justice, forest and water resources management, urban development, ecological and social well-being, and Indigenous Knowledge—will be integral for the future of living with fire (Roos et al. 2021; U.S. Congress 2022; Mockrin et al. 2022).

Sources

3.6 Ecological disruption

Florida

The United States and its territories are experiencing widespread ecological disruption. These effects range from regime shifts within ecosystems to biological disturbances across species. Rising temperatures, changes in precipitation patterns, and shifts in seasonality impact the biological, ecological, and geographic components of a region and, as a result, the ecosystem services provided to local communities (Brierley and Kingsford 2009; Pearson 2019; McAllister et al. 2022).

An *ecosystem* consists of all of the biotic (living organisms), as well as the abiotic (physical and chemical, such as the weather and landscape) components interacting within a geographic area. *Ecosystem services* are the benefits directly and indirectly provided to humans from the natural environment. These services range broadly—from the provision of food and fresh water to the sequestration and storage of carbon. Ecosystem services can be categorized into four broad categories: *provisioning* services (fresh water, food, fuel), *regulating* services (regulation of temperature, carbon sequestration and storage), *supporting* services (the cycling of nutrients, maintenance of biodiversity), and *cultural* services (outdoor recreation, ecotourism, and/or spiritual and religious value). The effects of climate change can be extremely disruptive to the structure and dynamics of ecosystems and to the health, well-being, and function of human society (Mooney et al. 2009; Weed et al. 2013; Fu et al. 2013).

Healthy ecosystems are many communities' first line of defense against environmental hazards. The variety of ecosystems throughout the southeastern United States provide numerous services, including the support of marine, aquatic, terrestrial, and avian biodiversity throughout the region. Saltwater marshes, estuaries, mangrove swamps, hardwood hammocks, and pine flatwoods provide flood protection, erosion control, climate mitigation, and play a major role in maintaining air and water quality. Sea dunes protect shorelines from erosion and provide habitat and nesting grounds for threatened and endangered species, such as gopher tortoises and sea turtles. The impacts of climate change experienced in the state of Florida—extreme temperatures, flooding events, and storms of increasing frequency and severity, for example—may put these ecosystems services and the communities dependent on them at risk (Haer et al. 2013).

In addition to (and synchronously with) compounding challenges in weather, water, and climate, human activity has a direct impact on ecological systems. The excessive usage of fertilizers for agriculture and landscaping can spur harmful algal blooms and cause massive mortalities in marine and aquatic ecosystems (Anderson et al. 2021). The deliberate or inadvertent introduction of new invasive species by humans, such as the rapidly spreading Brazilian peppertree (USDA 2024), can displace native species and reduce local biodiversity (Van Driesche et al. 2002). Inadequate waste management systems allow large concentrations of pharmaceuticals and plastics to accumulate in the marine environment (Castillo et al. 2024). Changes in land use due to increasing development and urbanization can adversely affect biological communities by reducing habitat area and connectivity, the availability of natural resources, and air and water quality. Throughout history, humans have driven species to extinction through overexploitation and overconsumption, and have consequently altered the structure and function of ecosystems. Both anthropogenic activities and the effects of a changing local, regional, and global climate pose a great risk to the well-being of biological communities and the provision of ecosystem services.

Weather, water, and climate have a wide range of impacts on the biotic and abiotic components of an ecosystem. Changes in temperatures can affect ecological, biological, and geochemical systems, causing shifts in the geographic ranges and phenology of species, influencing vitality and reproductive capability, and the cycling of nutrients. Marine heatwaves can cause massive bleaching and die off events in coral reefs, reducing the resiliency of both local fish populations and coastal communities. Warming temperatures can cause species to expand their geographic ranges, moving into areas that historically may not have been suitable habitats, as can be observed in the expansion of mangroves along Florida’s Atlantic coastline, gradually displacing salt marshes and altering the ecology of the landscape (Cavanaugh et al. 2019, Osland et al. 2022). Warming temperatures can also be devastating to already threatened or endangered species, such as the five species of sea turtles that nest on Florida’s beaches. The biological sex of sea turtles is determined by the incubation temperature of the eggs within their nests [known as temperature-dependent sex determination (TSD)]. These species are increasingly threatened as warming temperatures reduce their sexual and genetic diversity, with the majority of sea turtle hatchlings being female due to these warmer incubation temperatures (Mitchell and Janzen 2010).

A green sea turtle, a threatened species in the North Atlantic, cruises through sea grass. Photo by Isabella Herrera

Although historically the physical (and particularly the atmospheric) sciences have been considered distinct and disconnected from the biological sciences, a more interdisciplinary and intersectional approach is necessary to address the compounding challenges of WWC at the ecosystem level and beyond. Analogous to WWC, ecosystems and ecosystem services may transcend municipal boundaries, posing a challenge for environmental and resource management. Ecological forecasting is a rapidly growing area of research that integrates various scientific disciplines and presents broad opportunities for the advancement of science and decision-making. A recent statement from the AMS delves into the opportunity to incorporate knowledge acquired within the WWC enterprise—in particular, numerical weather prediction and climate modeling—to the advancement of ecological forecasting (American Meteorological Society 2024). More accurate monitoring and prediction of ecosystem change can reduce losses of biodiversity and increase resilience in both ecological and human-made communities. There is immense opportunity, for example, with the intersection of forecasting marine heatwaves, monitoring coral reef health, and predicting coral bleaching events in South Florida to better protect coral reef ecosystems, local fisheries, and coastal infrastructure.

The population of Florida has been growing rapidly over the last few decades. With large influxes of people and increasing development across the state, a consideration of conservation biology is vital to effective ecosystem and resource management, increasing community resilience, and the mitigation of climate change impacts. Land acquisition programs and expanding protected areas, such as through the Florida Forever Program and conservation of the Florida Wildlife Corridor, can prevent further losses of native ecosystems and protect biodiversity. Where land acquisition is not possible, acquiring and establishing conservation easements in areas zoned for future development can avoid losses of biodiversity, mitigate the disruption of ecosystems, and protect ecosystem services. Additionally, the implementation of ecosystem-based (nature-based) solutions—such as the conservation and restoration of natural shorelines to combat coastal erosion—into community planning, development, and adaptation efforts can build community resilience and adaptive capacity (Hoctor et al. 2000; Tucker 2001; Albert et al. 2014; FEMA 2021).

Sources

Wetlands in North Central Florida. These ecosystems play a major role in maintaining water quality and supporting biodiversity. Photo by Isabella Herrera

4. Conclusions

The United States and its associated territories uniquely experience challenges in weather, water, and climate (WWC) ; equity, inclusion, and justice (EIJ) ; and the intersection of WWC and EIJ. Storms of increasing frequency and severity can be devastating for underserved communities with limited critical infrastructure and disaster response capabilities. Hydrologic extremes—flooding and drought—present immense challenges for agriculture and water resources management. The compounding challenges of extreme temperatures, wildfires, and the disproportionate exposure of marginalized communities to pollution showcases the intersection of issues in climate, public health, and environmental justice. In addition to (and synchronously with) climate change impacts, human activity is directly impacting the function and well-being of ecological systems across the country and, consequently, the provision of ecosystem services. Socioeconomic and WWC vulnerabilities are inextricably linked, are uniquely experienced at the local level, and transcend geographic and political boundaries.

Challenges in WWC can exacerbate existing socioeconomic vulnerabilities, and historically underserved communities are disproportionately impacted by climate and weather hazards. People living in rural areas may be excluded from considerations of federal and state disaster assistance, despite already having less resources available for extreme weather preparedness and response. U.S. territories and Indigenous people have historically been excluded from decision-making, even in decisions pertaining to and directly impacting their own communities, and are disproportionately impacted by challenges in WWC and EIJ.

Given the complexities and interconnectedness of challenges in WWC and EIJ, climate adaptation efforts must be tailored to communities at the local level in order to effectively build community resilience, realize opportunities in WWC and EIJ, and serve all people across the United States and associated territories.

Just as there is extensive overlap between the challenges faced by each state/territory, there is also an intersection of potential opportunities for these communities in both WWC and EIJ. These opportunities include but are not limited to the following: *renewable energy*, *climate-resilient agriculture*, *adaptation of infrastructure*, *ecosystem conservation, restoration*, *and management, community engagement and education*, and *Indigenous Knowledge and sovereignty*.

- ***Renewable energy:*** Investments in renewable energy can increase the safety and reliability of energy systems in local communities, reduce their exposure to harmful pollutants, and alleviate energy insecurities. Ensuring that the transition to renewable energy is accessible and affordable for all communities is critical.
- ***Climate-resilient agriculture:*** Climate-resilient agricultural practices, such as prioritizing soil health and selecting heat-tolerant crops, can alleviate food insecurity and strengthen local economies. Agriculture is a major economic driver in many states and territories, and building resilience within this industry is essential for these communities' wellbeing.

- ***Adaptation of infrastructure:*** Adaptation of physical and social infrastructure will allow communities to be more healthy, connected, and resilient, especially in the face of an increasingly volatile climate. Increasing community connectivity and availability of resources for rural areas can build resilience at the local level.
- ***Ecosystem conservation, restoration, and management***: A consideration of conservation biology and ecological processes is integral to effective ecosystem conservation, restoration, and management. The implementation of ecosystem-based (nature-based) solutions into community planning, development, and adaptation efforts can increase the resilience and adaptive capacity of both ecosystems and local communities. Ecological forecasting presents a unique opportunity to integrate the physical, biological, and ecological sciences.
- ***Community engagement and education***: Education and outreach programs are a key component of extreme weather preparedness and can empower residents to increase their resilience and adaptive capacity at the household, neighborhood, city, county, and state levels. A strong foundation in environmental and climate education for all individuals can empower local leaders to make informed decisions and strengthen the weather, water, and climate workforce from the bottom-up.
- ***Indigenous Knowledge and sovereignty:*** The convergence of western (non-Indigenous) and Indigenous weather, water, and climate sciences presents an opportunity to address the impacts of colonialism on these communities and to acknowledge the value of Indigenous science in and of itself. Indigenous people and Native Tribes having the right to practice and preserve their cultures, and to protect and manage their historic lands, can alleviate both environmental and societal stressors that have for years disproportionately impacted their communities.

Addressing challenges in WWC from a more holistic and interdisciplinary approach can aid in rectifying issues in EIJ. Challenges experienced at the local level, especially in historically marginalized communities (e.g. Black, Latino/e, Indigenous, LGBTQ+, immigrant, and/or elderly populations), have often been overlooked in discussions of advancing science, scientific services, and policy. Decisions made for communities from the top-down may not accurately reflect the experiences of people at the local level and, therefore, do not effectively serve these communities or address their present problems.

The representation and inclusion of all people—irrespective of race, ethnicity, gender, national origin, disability, age, sexual orientation, gender identity, or other significant sociocultural identities—across the United States and the WWC enterprise is integral to combating challenges in weather, water, and climate and remedying long-standing issues of equity, inclusion, and justice.

5. Resources

I. EJScreen: Environmental Justice Screening and Mapping Tool
II. Applied Climate Information System (ACIS)
III. The Climate Prediction Center (CPC) U.S. Hazards Outlook
IV. Green2.0's Environmental Experts of Color Database
V. NOAA's Billion-Dollar Weather and Climate Disasters
VI. USDA Rural Development Disaster Assistance
VII. USDA Caribbean Drought Learning Network
VIII. Aqueduct Water Risk Atlas
IX. UCAR Network of Experts
X. EPA Interactive Map of Air Quality Monitors
XI. SciLine
XII. NIHHIS Urban Heat Island Mapping Campaign Cities
XIII. Climate Change, Health, and Equity: A Guide for Local Health Departments
XIV. U.S. Climate Resilience Toolkit
XV. U.S. Geological Survey: Baseflow Forecasts for Selected Sites in the United States
XVI. World Bank Climate Change Knowledge Portal
XVII. Equity Mapping and the Geography of Opportunity | HUD USER
XVIII. FEMA Social Vulnerability Index
XIX. National Water Center Products and Services Operational and Experimental
XX. Fifth National Climate Assessment
XXI. University of Alabama: Cooperative Institute for Research to Operations in Hydrology
XXII. Texas Energy Poverty Research Institute
XXIII. NWS HeatRisk
XXIV. National Center for Atmospheric Research (NCAR) Rising Voices
XXV. Conservation Technical Assistance

6. Glossary

Adaptation	an adjustment in a natural or human system in response to a new or changing environmental condition, including such an adjustment associated with climate change, that exploits beneficial opportunities or moderates negative effects
Adaptive capacity	the ability of a community to adapt to changing environmental conditions to effectively reduce harmful impacts and realize opportunities
Biodiversity	the variety of all life on Earth (at all levels, ranging from genes to organisms to ecosystems to the biosphere)
Community-based adaptation	a community-led initiative aiding people in adapting and responding to the impacts of climate change and building resilience locally
Ecosystem	all of the biotic and abiotic components interacting within a geographic area
Ecosystem services	the benefits directly and indirectly provided to humans from the natural environment, including *provisioning*, *regulating*, *supporting*, and *cultural* services
Equity	the fair opportunity for all people to fully benefit from and contribute to the insights, applications, and services of the enterprise
Evapotranspiration	the transfer of water from the land to the atmosphere; the loss of water from both the soil and the crops
Fire Weather Watch	a Fire Weather Watch is issued up to 72 hours before fire weather conditions (when the combination of dry fuels and weather conditions support extreme fire danger) are expected to occur

Fuels	dry vegetation that can catalyze wildfires in forests and shrublands
Gentrification	a shift in community demographics–due to an influx of wealthier individuals, increases in development, and property investment–that often exclude and displace historically underserved communities
Inclusion	the active and deliberate pursuit of creating a society where all are welcome, respected, and able to participate and contribute
Infrastructure (*physical* or "*critical*")	physical (or *critical*) infrastructure refers to the built environment of a community needed for a population to thrive and survive, including: road- and high-way systems, sewage systems, and utilities such as water and electricity
Infrastructure (*social*)	social infrastructure refers to the resources and services within a community (such as public education and healthcare) that support citizens' wellbeing
Justice	the fair treatment of all, including with respect to opportunity, accountability, and restitution. This includes, to the extent possible, making amends for past wrongs and repairing relationships with those who have been negatively impacted by past actions
Managed retreat / coastal realignment	the voluntary and coordinated relocation of people away from areas of high risk (such as eroding coastlines)
Mitigation	efforts to reduce the loss of life and property by lessening the impact of disasters
Red Flag Warning	a Red Flag Warning is issued when fire weather conditions (when the combination of dry fuels and weather conditions support extreme fire danger) are occuring or are expected to occur within 24 hours
Resilience	the ability of a community to prepare for and respond

	to environmental disasters, including extreme weather events
Indigenous sovereignty	a movement emphasizing the right of Indigenous people and Native Tribes to govern themselves, practice and preserve their cultures, and to protect and manage their historic lands
Urban heat islands	concentrations of higher air and surface temperatures in urban areas, often due to limited or nonexistent green spaces among buildings and roadways
Wildland-urban interface (WUI)	the area of intersection between wildlands and densely populated urban developments
Vulnerability	the degree to which a community (the people and/or the built and natural environment) is exposed to and impacted by challenges and hazards

7. Database

WWC & EIJ: Challenges & Opportunities

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