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BRIEFING PAPER

Data for Climate Risk Assessment in Vulnerable Communities

CODE

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Climate change poses an increasing risk to the environment and infrastructure around the world. The effects of climate change will disproportionately impact vulnerable communities, including minorities, low-income individuals, the elderly, and children. To combat the growing effects of the changing climate, the Federal government and state and local governments are developing robust climate risk assessment models to predict future climate hazards and develop mitigation plans.

In this Briefing Paper, the Center for Open Data Enterprise (CODE) analyzes the ways in which climate change is causing a disproportionate level of risk for vulnerable communities within the United States. These communities are impacted by two types of concerns: *climate hazards*, defined here as the physical hazards most likely to strike a geographical area (e.g. fires and floods), and *capacity*, which reflects the level of a city or community's financial, technical, and infrastructural resources to deal with those hazards.

The combination of low capacity and the likelihood of exposure to hazards determines climate risk. This paper provides an overview of climate hazards faced by different regions in the U.S. and the socioeconomic and other factors that can make communities especially vulnerable to those hazards. It reviews Federal, state, and local case studies that show how data is being used to address climate risk. Finally, the paper describes several resources for climate and weather hazard data resources and climate risk models from government and industry.

This Briefing Paper has been prepared as background for an upcoming *Roundtable on Data for Climate Risk Assessment in Vulnerable Communities* to be co-hosted by CODE and the National Oceanic and Atmospheric Administration (NOAA). It is also designed to be a useful resource for any individuals or organizations with an interest in this field. Information and opinions in this report do not necessarily reflect the opinions of NOAA or any other component of the federal government. CODE thanks its project partners, the Amazon Sustainability Data Initiative and Amazon Web Services, for supporting our work on this Briefing Paper and the Roundtable.

INTRODUCTION

Increasingly frequent and severe extreme weather conditions, growing populations, and increasing urbanization around the world are creating new challenges for governments and communities. The growing, global effects projected by climate change models are only expected to intensify, with the worst impacts happening at the local scale. Vulnerable communities will be especially impacted by coastal flooding, water scarcity, heat waves, and a host of other hazards, which disproportionately impact low-income households and communities of color across the United States. States, local governments, tribes, and territories are increasingly relying on physical climate data to build resilience strategies against critical climate threats to their populations and infrastructure.

To manage the impacts of climate change, governments and their partners need access to meaningful and authoritative data and information. Data standards and best practices will need to be developed to measure, mitigate, and monitor climate-related risks, and communities will need to tailor data-driven solutions to their local circumstances. Both the public and private sectors will need to contribute expertise and capacity to create a robust data value chain that delivers data and information to decision makers at the national and local level. Appendix 2 of this paper presents CODE's analysis of stakeholders at the various stages of data production and how they support the value chain for climate risk data.

On June 23 and 24, 2021, the National Oceanic and Atmospheric Administration (NOAA) and the nonprofit Center for Open Data Enterprise (CODE) are co-hosting a *Roundtable on Data for Climate Risk Assessment in Vulnerable Communities* to address these issues. The Roundtable will have the following objectives:

- Bring together communities that have developed and implemented impactful risk assessment plans and strategies to share lessons learned.
- Identify existing gaps in data and knowledge for vulnerable communities to manage climate risks, including challenges in accessing and using data.
- Identify emerging types of high-value climate-relevant data used to assess climate risk
- Provide perspective on how private sector stakeholders, like insurance companies, have sought to assess climate risk through data.
- Identify strategies to define and share best practices for incorporating data into climate resilience.
- Discuss high-value solutions and options, such as data exchanges and data sharing agreements, to make key data more accessible to local, state, tribal, and territorial governments.
- Engage government and private sector stakeholders in conversations about emerging technologies and data strategies to promote better data processing, sharing, and application.

While climate risks are a concern across the globe, this *Roundtable on Data for Climate Risk Assessment in Vulnerable Communities* will focus on data for assessing and addressing climate risk in the United States. This briefing paper describes issues, frameworks, data sources, and models from a U.S. perspective.

CLIMATE CHANGE AND CLIMATE RISK: FRAMEWORKS FOR ANALYSIS

Climate change is already making an observable impact on the environment worldwide, as previously predicted.[1] Glaciers and ice covering bodies of water are shrinking more rapidly, sea levels are rising, and weather patterns are increasingly intensifying, as seen with longer and more severe hurricane seasons. Since 1970, the global average temperature has been rising at a rate of 1.7 degrees Celsius per century, confirmed by both satellite measurements and analysis of hundreds of thousands of independent weather station observations globally.[2]

Even worse, regions affected by severe climate change conditions are expected to grow both in number and size as average temperatures rise, according to multiple climate models.[3] Coastal areas, for example, are experiencing a greater risk of being impacted by hurricanes. The intensity of hurricanes and the amount of destruction they cause are rising due to warmer temperatures, population growth, and a host of other factors.[4] The same can be said for wildfires, as their intensity and destruction of property and land increase as well. States like California, Texas, and North Carolina are experiencing larger wildfires, while states like Alaska, which has a relatively low number of fires, are experiencing disproportionate amounts of destruction due to inadequate capacity to deal with such events.[5] These increasing hazards, in addition to greater flooding, droughts, pollution, and heat waves, are all examples of the increasing impact of climate change, and will have major impacts on land use, food, and water security.

Cities in the U.S. have responded to increasing climate risk in a variety of ways. Some, such as Los Angeles and Boston, have developed data-driven models to analyze their growing risk of climate-related disasters and develop strategies to manage their risk. The last section of this paper provides a sample of current national, state, and city-based strategies, the tools they have developed, and the ways they have collected geographically localized data. These case studies can serve as models that could be adapted for other cities and other regions.

While some models are focusing on risk, others are focusing on mitigation, adaptation, resilience, or a combination of efforts. Mitigation involves efforts to reduce greenhouse gas emissions that cause climate change and raise the likelihood of climate hazards.[6] Climate adaptation refers to adapting to our changing climate, by adjusting to the current and expected future climate state.[7] Climate resilience, as defined by the Center for Climate and Energy Solutions, is the ability to anticipate, prepare for, and respond to hazardous events, trends, or disturbances related to climate change.[8] Many current climate resilience efforts are focusing on risk analysis to understand the current patterns and future risks of climate change to support mitigation, adaptation, and resilience models and strategies.

Climate Risk Framework

CODE and NOAA plan to structure the Roundtable around two types of concerns: *climate hazards*, defined here as the physical hazards most likely to strike a geographical area (e.g. fires and floods), and *capacity*, which reflects the level of a city or community's resources to deal with those hazards. The combination of low capacity and the likelihood of exposure to hazards determines climate risk.

Climate change is disproportionately impacting low-income communities and communities of color, which have both a higher likelihood of being impacted by climate-related hazards (e.g. from urban heat islands or floods) and low financial and socioeconomic capacity.[9] These communities will more likely struggle to access, process, and share locally relevant datasets that help them identify, manage, and adapt to climate risks and build climate resilience. CODE and NOAA will use this framework in their upcoming *Roundtable on Data for Climate Risk Assessment in Vulnerable Communities* to help identify community-based approaches that have been effective, especially in high-risk communities.

	HIGH LIKELIHOOD OF HAZARD	LOW LIKELIHOOD OF HAZARD
LOW CAPACITY	***High Risk*** Communities that have poor infrastructural and financial capacity and face high likelihood of exposure to climate-related hazards.	***Medium Risk*** Communities that have low likelihood of exposure to climate-related hazards but also low infrastructural and financial capacity.
HIGH CAPACITY	***Medium Risk*** Communities that have strong financial and infrastructural capacity and relatively high threat of exposure to climate-related hazards.	***Low Risk*** Communities that have strong financial and infrastructural capacity and face low likelihood of exposure to climate-related hazards.

A Data Value Chain Framework

In preparation for the upcoming Roundtable, CODE has also created a climate risk data value chain that analyzes the various stages and stakeholders involved in the climate risk data production process. This analysis outlines how data is produced in the climate risk sector and who is responsible for its collection, sharing, analysis, and stewardship. For a more detailed description of this analysis, please see Appendix 2.

CLIMATE RISK DATA STAGE	DESCRIPTION
Observation and Collection	New observational data gathered manually from humans or automatically through sensors and satellites.
Quality Control and Input	The entry of valid climate risk observational data into a storage system that can be done manually or automatically.
Processing	Raw data that has been entered is then manipulated and computed before being saved in a specific file format.
Storage and Archiving	Processed information is shared and stored in various locations like data lakes or data containers.

CLIMATE RISK DATA STAGE	DESCRIPTION
Publishing and Products	Data is published either through data visualization or packaged into products for use by industry in sectors like real estate, energy, and agriculture.
Application and Analysis	After data is processed, stored, and published in online portals, it can be applied and analyzed by a variety of stakeholders.
Assessment and Revision	Data used by the field may be adjusted to better fit expectations and uses by industry, government, and civil society.

Community Vulnerability: A Socioeconomic Impact Framework

The McKinsey Global Institute has created a framework to measure the socioeconomic impacts of climate change, which can help determine a community's climate vulnerability and capacity to deal with climate hazards. The framework measures impact by looking at the extent to which the effects of climate change can disrupt or destroy human life, and physical and natural capital.[10] This framework analyzes five different areas of social impact using an established research methodology and integrating multiple units of analysis. This framework is of particular relevance to the Roundtable topic, as socioeconomic status is an important factor in determining a community's vulnerability and capacity to face climate hazards. The table below is taken from the January 2020 McKinsey report that presented this framework.[11]

LIVABILITY AND WORKABILITY	Hazards like heat stress could affect the ability of human beings to work outdoors or, in extreme cases, could put human lives at risk. Increased temperatures could also shift disease vectors and thus affect human health.
FOOD SYSTEMS	Food production could be disrupted as drought conditions, extreme temperatures, or floods affect land and crops, though a changing climate could improve food system performance in some regions.
PHYSICAL ASSETS	Physical assets like buildings could be damaged or destroyed by extreme precipitation, tidal flooding, forest fires, and other hazards.
INFRASTRUCTURE SERVICES	Infrastructure assets are a particular type of physical asset that could be destroyed or disrupted in their functioning, leading to a decline in the services they provide or a rise in the cost of these services. This in turn can have knock-on effects on other sectors that rely on these infrastructure assets.
NATURAL CAPITAL	Climate change is shifting ecosystems and destroying forms of natural capital such as glaciers, forests, and ocean ecosystems, which provide important services to human communities. This in turn imperils the human habitat and economic activity.

Climate change exacerbates disparities in socioeconomic conditions: Those who suffer from socioeconomic inequalities are more likely to suffer detrimental consequences. The impacts of climate change are largely connected to a community's resilience and vulnerability levels. Minority communities have high rates of poverty: 20.8% of Black Americans, 17.6% of Hispanic Americans, and 25.4% of Native Americans live in poverty, compared to only 8.1% of non-Hispanic Whites. Because these populations disproportionately face poverty, they are more likely to reside in communities that have less resilient infrastructure development and lower financial capacity to face and recover from climate disasters.[12]

CLIMATE HAZARDS AND COMMUNITY VULNERABILITY

Certain communities are inherently more at risk of suffering the physical effects of a changing climate. These include areas prone to coastal flooding, wildfires, severe pollution, and other conditions exacerbated by climate change. The New York Times and the American Communities Survey, for example, have produced interactive maps to help counties visualize the types of hazards that will impact their communities. These maps help measure a county's susceptibility to heat stress, hurricanes, sea level rise, and other risks. This section describes the nature of these growing hazards and the regions and cities they are most likely to impact.

While this section describes different climate hazards separately, they can often interact to have a devastating impact. For example, many different hazards can dangerously disrupt water access and lead to food insecurity. Severe climate hazards like droughts, fires, pests, and diseases are wreaking havoc on the world's food production, and these issues are worsening. Increasing destruction from wildfires and storms in the United States are threatening crops and livestock, with millions of acres of corn and soybean production destroyed in a single *derecho* storm in the Midwest.[13] Food disasters in other countries are also disrupting global food supplies in ways that can impact American consumers: Locust swarms[14] are destroying huge amounts of crops across East Africa and Southwest Asia, while increased flooding[15] is putting critical strains on Chinese agriculture.

Food insecurity, like other climate-related impacts, is also likely to affect low-income and minority communities disproportionately. An analysis of food trends between 2001 and 2016 found that rates of food insecurity for the Black population and Hispanics was at least twice that of non-Hispanic white households.[16] Native Americans suffer some of the highest rates of food insecurity and diet-related diseases, with one out of every four indigenous people experiencing this type of insecurity, versus one in nine Americans overall.[17] The second half of this section describes how low capacity, such as a lack of financial resources or poor infrastructure, can intersect with the likelihood of hazards to put some communities at especially high risk from climate change.

How Climate Hazards Impact Different Areas

Hurricanes. The risk of being hit by a severe hurricane can vary by geographical area. States and areas at higher risk of experiencing hurricanes include Southeast Florida and the Florida Panhandle, Louisiana, Texas, the coastal areas of Mississippi and Alabama, and Puerto Rico. Climate change is both putting more communities at high risk of experiencing a hurricane, and increasing the chances of property destruction and human injury/casualties from hurricanes as well. This is not necessarily due to an increase in prevalence, as the number of hurricanes has held fairly steady over time. Rather it is caused by two factors: The population has increased in coastal areas, creating a greater opportunity for damage, and the intensity of cyclones and hurricanes has increased and is likely to worsen, with more storms reaching category four and five.[18]

Wildfires. Although the number of wildfires has decreased in recent years, fires are becoming more intense and growing larger and more devastating. In the past 20 years, more acres of land have succumbed to wildfires than in the 40 years before that. This trend appears to be increasing. The state of California is especially susceptible to wildfires: Four of the five largest wildfires in the state's history occurred in 2020 alone.[19]

Among U.S. states, from 2015 to 2019 Texas has had the highest annual average of wildfires with 9,166 fires, followed by California, North Carolina, and Georgia.[20] This ranking, however, does not necessarily reflect the amount of destruction from fire in each state. For example, Alaska has had almost twice as many acres burned as California, with more than 1.8 million acres burned on average per year between 2015 and 2019, while it has had far fewer wildfires: only 558 wildfires in the timeframe, compared to 8400 in California. The higher level of destruction in Alaska could have to do with disparities in state infrastructure capacity and resources available to fight such fires.[21]

Although many wildfires burn in underdeveloped and underpopulated areas, they can still have catastrophic impacts on human lives, development, and communities. Colorado, for example, ranked 14th in the number of acres of land burned per year on average, but ranked third highest in number of properties at risk of wildfire damage.[22] California, which ranks first in the number of homes at risk of wildfire damage, experienced a wildfire in 2018 that was not even one of the 20 worst in the state's history (in terms of the area burned) but ended up being the most destructive, resulting in 19,000 structures destroyed and 85 lives lost.[23]

Droughts. The impact of drought is already causing detrimental effects on water access and food security. Projected increases in global temperatures will lead to significant decreases in freshwater sources and agricultural development in the near and long-term future.[24] Access to clean water is becoming increasingly difficult, particularly in areas that already experience high water vulnerability, meaning they lack sufficient fresh water to meet daily needs.[25] When extreme weather disasters hit, they can contaminate or destroy entire water systems. Approximately 74 percent of natural disasters between the years of 2001 and 2018 were water-related, including droughts and floods. As of 2021, 450 million children live in areas of high or extremely high water vulnerability.[26] Rising temperatures also pose a risk to water purity, as they can lead to deadly pathogen growth in fresh water sources.

Sea-Level Rise. The average of global sea levels has risen about eight to nine inches in the past century and a half, mostly due to melting glaciers and ice sheets and thermal expansion of seawater.[27] In certain ocean basins, sea levels have risen six to eight inches since 1993.[28] Rising sea levels pose a high risk to American cities because almost 40 percent of the population resides in high population density coastal areas, which will see increased flooding, shoreline erosion, and storm hazards.[29] Sea-level rise also poses risks to water access for some coastal communities, as saltwater intrusion associated with sea-level rise can impact groundwater availability.[30] Coastal cities across the United States, such as Miami, Boston, and New Orleans, have begun to evaluate how they can prepare for the impact of these rising water levels through improved urban design, environmental restoration, and engineering solutions.

Heat Waves. As the climate continues to warm, heat waves in the U.S. are becoming longer and more frequent, increasing from an average of two heat waves per year in the 1960s, to over six during the 2010s.[31] Additionally, the average heat wave season has extended to 47 days longer than it was in the 1960s across 50 major cities in the U.S.[32] These increases in hotter days are leading to more heat-related deaths and illnesses, particularly in vulnerable communities. Urban areas are already more vulnerable to challenges related to heat, as they experience hotter surface air temperatures than rural and suburban areas, an occurrence known as urban heat island effect.[33] Heat islands are caused by different factors including greater numbers of buildings, vehicles, and industry, which increases a city's release of concentrated heat.[34] This growing effect is detrimental to public health, disproportionately impacting children, the elderly, those who work outside, and those with respiratory illnesses and other pre-existing conditions. Research from the Environmental Protection Agency has shown that low-income and minority groups have high rates of asthma and are also likely to live or work in "intra-urban" heat islands, a combination that puts them at high risk of adverse health outcomes.[35]

Communities at High Risk: How Climate Hazards and Vulnerability Intersect

The combination of low community capacity and a high likelihood of hazards can lead to devastating impacts from climate change, and minority communities are often at high risk. Historic and pervasive discrimination has often resulted in poor investment in these communities. For example, New Orleans has historically suffered from poor flood risk infrastructure. Hurricane Katrina caused an estimated $81 to 150 billion in property damages, and claimed over 1,800 lives, almost half of which were among people over 75.[36] Additionally, most of the people affected by the hurricane and ultimate failure of the levees were African Americans, who in 2005, made up 60.5% of the city's population.[37]

Indigenous people in the U.S. and around the world also experience a greater impact of climate change, due to "their dependence on, and close relationship, with the environment and its resources," according to a United Nations report.[38] These communities already face a disparate degree of political and economic marginalization, loss of land and resources, human rights violations, discrimination, and unemployment.[39] All these factors increase the risk of negative impacts from the changing climate.

The health impacts of climate change are closely related to the social determinants of health (SDOH), which are defined as the "conditions in which people are born, grow, live, work and age that shape health."[40] Climate and environmental factors, a key type of SDOH, play a critical role in the health of individuals and health disparities between groups. Key types of climate and environmental data include air and water quality, access to clean water, and exposure to power plant emissions. Climate change is worsening overall health outcomes, increasing costs of care, and exacerbating the effects of other social determinants of health, all of which disproportionately impact vulnerable communities.[41] Hazards such as longer and hotter summers, frequent and more intense storms, rising sea levels, more severe droughts, and deteriorating air quality are associated with health risks.[42] The health impacts include worsening asthma and allergy symptoms, physical trauma from disasters, and mental health symptoms such as post-traumatic stress and other anxiety disorders.

The health effects of extreme weather events caused by climate change are especially devastating for vulnerable populations, such as low-income individuals, people with disabilities, pregnant women, children, and minorities.[43] These populations are often more susceptible to disease and illness, have preexisting health conditions, live in areas that do not promote good health or well-being, or have decreased access to quality healthcare. For example, groups that are most affected by air and other types of pollution are minorities, the elderly, children with uncontrolled asthma, and those in poverty.[44] These populations may experience more severe health effects due to already higher rates of heart and lung conditions.[45] Additionally, new research shows that communities with elevated levels of air pollution have more severe health outcomes and rates of death from COVID-19.[46] Climate change-related events that lead to evacuation, such as flooding, are also devastating to vulnerable groups.[47]

Other environmental hazards that are not directly related to climate change may disproportionately affect vulnerable communities, and may interact with climate hazards in destructive ways. In addition to growing climate hazards, for example, many communities are also exposed to greater levels of air pollution. According to the 2021 American Lung Association "State of the Air" report, over 40 percent of people in the U.S. are living in areas with unhealthy levels of ozone or particle pollution, and people of color are over three times more likely to be breathing the most polluted air than white people.[48] Additionally, the threat of deadly air pollution is consistently worsening by the year, and in 2021, an increase of almost 1.1 million more people were living in areas with unhealthy levels of particulate matter pollution.[49]

Low-income and minority communities, including Hispanic, Black, and Native American communities, are less likely to have the financial resources and infrastructural capacity to prepare for and recover from extreme climate events. For example, in the immediate aftermath of climate disasters, Federal Emergency Management Agency (FEMA) aid disbursements are more directed towards homeowners than renters.[50] But housing shortages following climate disasters result in increases in rent prices that low-income households are least able to afford. Additionally, these households are more likely to reside in areas with greater exposure to natural hazards and less likely to live and work in areas with infrastructure resilient enough to withstand climate disasters.[51]

Miami Dade County is one community that has particularly high climate risk, with both low capacity and a high risk of experiencing climate hazards. The county is at a severe risk of being underwater and suffering the harsh consequences of sea-level rise. With just a six inch increase in sea rise, Miami would turn back into a wetland environment. Miami's water supply is already heavily dependent on water from the Everglades ecosystem, which sometimes dries out during droughts. Projected increases in chronic droughts will undoubtedly affect Miami's already threatened water supply. Additionally, because 79 percent of the county's properties are located in coastal areas, they are also at an increased risk of damage and infrastructural failure due to beach erosion.[52] As sea levels rise, coasts are diminishing at a faster rate, leaving coastal properties more vulnerable to damage from storms and waves.

Miami Dade County will also suffer the effects of rising temperatures. The county is highly urbanized, and concrete urban structures absorb and radiate heat. As Miami's temperatures rise with global warming, heat islands will continue to grow and summers will become increasingly hotter, with a high impact on urban minority communities.[53]

CASE STUDIES: NATIONAL AND LOCAL MODELS AND SOLUTIONS

A Federal Strategy: Justice40

The Biden Administration has prioritized climate change through its Executive Order (EO) on "Tackling Climate Change at Home and Abroad." Among the directives in the EO was the development of an initiative known as Justice40. Justice40 is a federal program tasked with delivering 40% of overall climate funding to historically overburdened and underserved vulnerable communities. The EO also provides a list of recommendations to combat the growing effects of climate. Justice40 will utilize opensource approaches to ensure transparency and their participatory principles, to ensure that all software tools are available for public observation, input, and reuse.

The goals of Justice40 are to: Deliver government benefits and investments to the most historically overburdened communities; Enable community ownership; Improve their ability to measure environmental, economic, and climate justice metrics; and Build community trust. The EO also specifies that recommendations developed by the Initiative will focus on investments in the areas of clean energy and energy efficiency; clean transit; affordable and sustainable housing; training and workforce development; the remediation and reduction of legacy pollution; and the development of critical clean water infrastructure.

The recommendations will be developed by the Chair of the Council on Environmental Quality (CEQ), the Director of the Office of Management and Budget, and the National Climate Advisor with consultation from the newly established White House Environmental Justice Advisory Council.

Local Case Studies

A number of cities and some states have started to apply national-level data from the models above for their own local needs. These cities have produced climate and vulnerability risk assessments that are specific to their municipalities.

Arizona

ADOT Resilience Pilot Program

- Climate change in Arizona is causing more deadly heat waves, droughts, and wildfires within the state.[54]
- The Arizona Department of Transportation (ADOT) is pursuing a "Resilience Pilot Program" (RPP) to improve data and modeling with the aim of reducing incidents of flood, hydraulic-related failure, and extreme weather damage to critical transportation infrastructure. ADOT seeks to combine risk, science, technology, and engineering to improve the understanding of weather-related risks to its transportation system. The current Resilience Program scope and goals are driven by a structured sequence to incorporate extreme weather and climate adaptation into the design engineering process, that also encompasses a risk-based, asset management, and life cycle planning approach.

- The program identifies the stressors that pose the highest threats to ADOT's transportation system by addressing the following:
  - Intense Precipitation
  - System Flooding
  - Wildfires
  - Wildfire-Induced Floods
  - Drought-Related Dust Storms
  - Rockfall Incidents
  - Slope Failures
  - Increased Surface Temperatures

Boston

Climate Ready Boston

https://www.boston.gov/sites/default/files/file/2019/12/02_20161206_executivesummary_digital.pdf

- As the climate continues to change, Boston will increasingly suffer from extreme heat, stormwater flooding, and coastal and riverine flooding.[55]
- Climate Ready Boston is an ongoing initiative that works with the community and other partners to advance the city's vision for a Climate Ready Boston. As climate continues to change, the chances of coastal and riverine flooding in Boston, as well as other hazards like stormwater flooding and extreme heat, will increase.
- To address these challenges, Climate Ready Boston features **four components**:
  - **Updated Climate Projections** — A set of updated projections for four climate factors: extreme temperatures, sea level rise, extreme precipitation, and storms.
  - **Vulnerability Assessment** — A comprehensive evaluation of current and potential future risks associated with each of three climate hazards (extreme heat, stormwater flooding, and coastal and riverine flooding) for Boston's people, buildings, infrastructure, and economy.
  - **Focus Areas** — Eight Boston areas where the results of the Vulnerability Assessment and the climate resilience initiatives are applied in more detail to illustrate the risks Boston faces and how Boston can address them. The focus areas recognize that some risk, particularly for coastal and riverine flooding, is spatially concentrated.
  - **Climate Resilience Initiatives** — These policy, planning, programmatic, and financial initiatives address the risks identified in the Vulnerability Assessment and work together to increase Boston's resilience. The initiatives are summarized in an Implementation Roadmap that sets forth, for each initiative, responsibility, time frame, and key milestones.

Detroit

Detroit Climate Action Plan

- Detroit will increasingly suffer from flooding and sewage overflows and heat waves as the climate changes.[56]
- The Detroit Action Plan provides an overview of the expected trends and impacts in Detroit, and strategies for mitigating emissions and preparing for climate risks. The plan grounds its recommendations in a vulnerability assessment - and analysis done by partner organizations assessing climate emissions in the city, and current trends. These trends find that Detroit is seeing warmer temperatures and that trend will continue. Air quality risks, increasing precipitation, and inland flooding are also projected to become greater hazards.
- **Impacts:** Air Quality; Air Temperature Precipitation Changes; Socioeconomic; Water Quality
- **Strategies and Goals:**
  - Solid Waste
  - Public Health
  - Businesses & Institutions
  - Parks, Public Spaces, & Water Infrastructure
  - Homes & Neighborhoods

Houston

Houston's Climate Future

- Houston Texas experiences a number of climate hazards including extreme heat, cold weather, flooding, hurricanes and tropical storms, tornadoes, and wildfires.[57]
- In 2020, the City of Houston published a Climate Action Plan for the city to adapt to and mitigate climate change. The Climate Impact Assessment will provide a better understanding of the heat, drought, and precipitation risks associated with carbon dioxide, and other heat-trapping gasses through energy transition, transportation, building optimization and materials management. The assessment summarizes observed and projected changes in temperature and precipitation for 11 long-term weather stations across the greater Houston area, and translates these into 25 different climate indicators, from the temperature of the hottest day of the year to projected changes in heavy precipitation.
- **Climate Indicators:**
  - Onset of summer; End of summer; Length of summer; Cooling Degree-days; Days per year above 100 degrees F; Nighers per year above 80 degrees F; Hottest day of the year; Hottest week of the year; Longest heatwave; Annual precipitation; Seasonal precipitation; Annual dry days; Wettest 3-day event; Very wet days; Return period of historical 100-year storm; SPEI drought index

Los Angeles

Integrated Vulnerability Assessment Framework

https://coastalscience.noaa.gov/news/lacounty-vulnerability-assessment/

- Los Angeles suffers from a variety of climate related hazards including bluff erosion, sea level rise, wildfires, saltwater intrusion, earthquakes, tsunamis, water availability, and air quality.[58]
- According to NOAA's description of Los Angeles' project, "Research identified and assessed social, structural, and natural resource vulnerability profiles for three geographies: the entirety of Los Angeles County, a 10-mile coastal band, and urban areas. Researchers developed risk profiles for flooding, erosion, drought, heat, and wildfire within each study area, and then intersected vulnerability with risk in a series of maps. These maps suggest that erosion is tightly interwoven with flooding impacts, wildfire threatens both rural and newly suburban areas, drought risk is likely to impact both rural and urban areas, heat risk is likely to occur further inland, and many areas of high social vulnerability are also at high flood risk."
- "Following initial assessment, researchers further explored National Flood Insurance Policy claims, access to green and cultural space, and impacts of erosion and flooding on critical infrastructure and blufftop development within the 10-mile coastal band. These analyses found that many high flood risk areas have fewer flood insurance claims, at-risk populations and areas lack green space, cultural resources are at risk of flooding, disaster routes are susceptible to both flooding and erosion impacts, and many areas of new development share high erosion risk."

Pittsburgh

Climate Action Plan 3.0

- Pittsburgh suffers from extreme heat, drought, wildfires, inland/coastal flooding, and stagnant air.[59]
- In 2007, "Pittsburgh's Green Government Task Force (GGTF) was charged with developing the first ever Pittsburgh Climate Action Plan, adopted by the City as a guiding document in July 2008. The Climate Action Plan 3.0 takes a renewed approach to climate change mitigation by presenting action plans and strategies regarding six key areas: Energy Generation & Distribution, Buildings & End Use Efficiency, Transportation & Land Use, Waste & Resource Recovery, Food & Agriculture, and Urban Ecosystems. The Climate Action Plan provides a road map for reducing Greenhouse Gas Emissions in the City of Pittsburgh while also improving the resilience, health, and overall quality of life for Pittsburgh residents."
- "While each area has specific goals and actions, there is significant overlap among action areas. This helps to create a more holistic plan that provides opportunities for greater impact through coordination across sectors. Of the six focus areas, the overlapping actions naturally create two action clusters; energy and ecosystems."

CLIMATE RESOURCES AND MODELS

The Federal Government, a number of state and local officials, and some private sector companies have developed data resources and models to assess climate hazards and community vulnerability. Federal agencies such as NOAA and the U.S. Department of Agriculture (USDA) have developed robust initiatives to support data collection, analysis, and stakeholder engagement to accurately assess the effects of our changing climate in various regions. These resources and models can be leveraged to support local initiatives and capacity building. Please note that this is not meant to be an exhaustive list, but to provide examples of resources and models that are now available.

Climate and Weather Hazard Resources

Amazon Sustainability Data Initiative (ASDI)

- **Overview:** ASDI currently works with scientific organizations like NOAA, NASA, the UK Met Office and Government of Queensland to identify, host, and deploy key datasets on the AWS Cloud, including weather observations, weather forecasts, climate projection data, satellite imagery, hydrological data, air quality data, and ocean forecast data.
- **Purpose:** Seeks to accelerate sustainability research and innovation by minimizing the cost and time required to acquire and analyze large sustainability datasets. ASDI facilitates the discovery of data from NOAA and other data providers around the world and makes it easily accessible and usable by researchers and innovators next to computational capabilities in the AWS cloud.
- **Datasets: ASDI holds additional datasets on their website and this is not a comprehensive list.**
  - NOAA Severe Weather Data Inventory.
    - **Overview:** An integrated database of severe weather events across the United States from 1950 to the present, with information about a storm event's location, distance, impact, and severity, including the cost of damages to property and crops. It contains data documenting the occurrence of storms and other significant weather phenomena having sufficient intensity to cause loss of life, injuries, significant property damage, and/or disruption to commerce.
  - NOAA National Water Model Short-Range Forecast
    - **Overview:** A water resources model that simulates and forecasts variables related to the water cycle, including snowpack, evaporation of water and transpiration from plants, soil moisture, and streamflow over the entire continental United States. The model is designed to improve the ability of NOAA to meet the needs of its stakeholders, including forecasters, emergency managers, and first responders, by providing expanded accuracy, detail, and frequency of water information.
  - Radar Produced Inundation Diary NRT Flood Maps
    - **Overview:** Near real-time and archival data of high resolution (10 m) flood inundation dataset over the Contiguous United States, developed based on the Sentinel-1 SAR imagery (2016-current) archive, using an automated Radar Produced Inundation Diary (RAPID) algorithm.

Climate Data Online (CDO, NOAA)

- **Overview:** NOAA's CDO provides free access to their National Centers for Environmental Information archive of global historical weather and climate data in addition to station history information. The data includes quality controlled daily, monthly, seasonal, and yearly measurements of temperature, precipitation, wind, and degree days as well as radar data and 30-year Climate Normals. Customers can also order most of these data as certified hard copies for legal use.[60]

- **Purpose:** To provide free access to the National Centers for Environmental Information archive of global historical weather and climate data in addition to station history information.

- **Key Activities:**
  - **Search Tool:**[61] Search for and access past weather and climate data by station name or identifier, ZIP code, city, county, state, or country.
  - **Mapping Tool:**[62] Find and view past weather and climate data by station name or identifier, ZIP code, city, county, state, or country. One can identify tool queries and display information about visible features on the map.
  - **Other Data Tools:** Access past weather and climate data using a collection of specialized tools.

USDA Climate Hubs

- **Overview:** The Hubs are a collaboration across USDA agencies. They are led by the Agricultural Research Service and Forest Service senior directors located at ten regional locations, with contributions from many other programs including the Natural Resources Conservation Service and the Farm Service Agency. The Hubs link USDA research and program agencies in their regional delivery of timely and authoritative tools and information to agricultural producers and professionals.

- **Purpose:** To develop and deliver science-based, region-specific information and technologies, with USDA agencies and partners, to agricultural and natural resource managers who can enable climate-informed decision-making, and to provide access to assistance to implement those decisions.

- **Key Activities:**
  - Research and science information synthesis
  - Tool development, technology exchange, and implementation assistance
  - Stakeholder education, outreach, and engagement

EJSCREEN

- **Overview:** EJSCREEN is an environmental justice mapping and screening tool that provides the Environmental Protection Agency (EPA) with a nationally consistent dataset and approach for combining environmental and demographic indicators. The tool allows users to choose a geographic area; then provides demographic and environmental information for that area. All of the indicators are publicly accessible data.

- **Purpose:** EJSCREEN allows users to access high-resolution environmental and demographic information for locations in the United States, and compare their selected locations to the rest of the state, EPA region, or the nation. The tool may help users identify areas with minority

and/or low-income populations, potential environmental quality issues, a combination of environmental and demographic indicators that is greater than usual, and other factors that may be of interest.

- **Includes**[63]
  - 11 Environmental Indicators
  - 6 Demographic Indicators
  - 11 EJ Indexes: Each index combines demographic indicators with a single environmental indicator

Risk Models

A number of Federal and state and local entities have created models for local climate risk assessment. These models serve as robust and innovative tools which predict events such as a state's risk of wildfire occurrence and destruction, and overall risk of numerous climate-related disasters by region.

Federal Models

FEMA National Risk Index for Natural Hazards

- **Overview:** A new, online mapping application visualizes natural hazard risk metrics and includes data about expected annual losses, social vulnerabilities and community resilience. The National Risk Index's interactive web maps are at the county and census tract level and made available via geographic information system (GIS) feature services for custom analyses. With this data, you can discover a holistic view of community risk to natural hazards via online maps and data.

- **Purpose:** An online tool to help identify communities most at risk of natural hazards. The tool calculates relative risk measurement at the state, county, and census tract level for 18 natural hazards.

- **Data:** Geographic information system (GIS) web layers for the National Risk Index can be accessed through The National Risk Index Group on FEMA's Hazards GeoPlatform (HGP) to use in your own web maps and apps. The following GIS layers are available:
  - National Risk Index Counties (October 2020)
  - National Risk Index Tracts (October 2020)
  - National Risk Index Hazard Info Table (October 2020)
  - National Risk Index Counties - Natural Hazard Annualized Frequency (October 2020)
  - National Risk Index Tracts - Natural Hazard Annualized Frequency (October 2020)

NOAA Regional Integrated Sciences and Assessments (RISA) Programs

- **Overview:** Supports research teams that help expand and build the nation's capacity to prepare for and adapt to climate variability and change. RISA produces actionable climate research, helping to reduce economic damages that Americans face every year due to droughts, floods, forest fires, vector borne diseases, and a host of other climate and extreme weather impacts.

- **Purpose:** RISA teams work with public and private user communities to:
  - Advance understanding of context and risk
  - Support knowledge to action networks
  - Innovate services, products and tools to enhance the use of science in decision making
  - Advance science policy
- RISA Regional Teams
  - Alaska Center for Climate Assessment and Policy
  - Consortium on Climate Risk in the Urban Northeast
  - Pacific Northwest Climate Impacts Research Consortium
  - Carolinas Integrated Sciences and Assessments
  - Climate Assessment for the Southwest
  - California-Nevada Climate Applications Program (CNAP)
  - Great Lakes Integrated Sciences and Assessments Center (GLISA)
  - Mid-Atlantic Regional Integrated Sciences and Assessments Center (MARISA)
  - Pacific RISA
  - Southern Climate Impacts Planning Program (SCIPP)
  - Western Water Assessment (WWA)

U.S. Department of the Interior (DOI) Climate Adaptation Science Centers (CASC)

- **Overview:** CASC funds scientific projects that generate research, data sets, and tools that natural and cultural resource managers can use to help fish, wildlife, ecosystems, and local communities survive and thrive in a changing climate.
- **Purpose:** CASC's mission is to use science to help wildlife, ecosystems, and people adapt to a changing climate. CASC works directly with land managers, native communities, and other partners to create research and tools that can be applied directly to adaptation decisions.
- Projects & Data: By region and by topic
  - Landscapes
  - Drought, Fire, and Extreme Weather
  - Wildlife and Plants
  - Water, Coasts, and Ice
  - Native Communities
  - Science Tools for Managers

USDA Wildfire Risk to Communities

- **Overview:** A free, easy-to-use website with interactive maps, charts, and resources to help communities understand, explore, and reduce wildfire risk. It was created by the USDA Forest Service under the direction of Congress and is designed to help community leaders, such as elected officials, community planners, and fire managers.

- **Purpose:** Provides publicly accessible data through interactive maps and charts showing risk to homes, exposure types, wildfire likelihood, and vulnerable populations.

State, City, Local Models

Cal-Adapt

- **Overview:** Provides a view of how climate change may affect California. Provides tools, data, and resources to conduct research, develop adaptation plans, and build applications. Provides access to state level data, critical to understanding and managing climate risks.
- **Data:** Climate datasets on Cal-Adapt include historical observations and climate projections. Each dataset consists of a collection of time series for one or more climate variables, multiple future scenarios and global climate models. All gridded climate datasets available on Cal-Adapt cover the entire state of California, and some extend further into parts of Nevada, Oregon, Idaho and Mexico. Users can download original datasets, export data into Cal-Adapt tools, or use Cal-Adapt API to use data.
- **Tools:**
  - Local Climate Change Snapshot — provides snapshot of what climate change means in certain areas, as change-related effects vary significantly throughout state of California
  - Annual Averages — allows users to explore projected annual averages of maximum and minimum temperatures, and precipitation for a location
  - Maps of Projected Change — allow users to explore maps of projected long-term changes in annual average temperature and precipitation

Industry Models

Jupiter Intelligence Climate Risk Analytics

- **Overview:** Jupiter Intelligence is an industry leader in climate risk analysis, with a number of products to predict and manage climate risk. Jupiter combines dynamic Earth System models with data-driven techniques to produce highly localized and current climate hazard estimates.
- **Products:**
  - Jupiter FloodScore — predicts the expected flood level in any designated area for a specific asset as small as a loading dock or on-premise flood protection. Users are able to prepare for potential flooding as it relates to a changing climate.
  - Jupiter HeatScore — predicts expected temperatures probabilistically across a range of heat variables necessary for informing load forecasting and planning, infrastructure design, and public health and safety.
  - Jupiter WindScore — delivers quantifiable analysis of changes in wind at very high spatial and temporal resolution and factors in local effects on wind.
  - Jupiter FireScore — captures current and future trends in drought, rain and forest health to predice wildfire risk in a changing climate.

CONCLUSION

This document will serve as background for CODE and NOAA's *Roundtable on Data for Climate Risk Assessment in Vulnerable Communities*. The structure of the Roundtable will focus on prioritizing communities who are at an increased risk of facing climate related hazards, and vulnerable communities that have lower capacity to deal with such hazards. Drawing on research from the Briefing Paper, Roundtable participants will identify existing gaps in data and knowledge for vulnerable communities to manage climate change, share knowledge and develop best practices from existing climate risk assessment models, and identify high-value solutions to make key data more accessible to local, state, tribal, and territorial governments through interactive breakout sessions. Following the Roundtable, CODE will prepare a public Summary Report of findings and recommendations based on the participants' work.

Beyond participants in the Roundtable, CODE hopes that this Briefing Paper serves as a useful resource for other individuals and organizations working to address climate change. Our efforts to deal with the impact of climate change must prioritize the communities at greatest risk. By considering both community vulnerability and the physical hazards of climate change together, governments, civil society, and the private sector can collaborate to find effective, data-driven solutions.

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The NOAA Office of the Undersecretary provides oversight, technical expertise & critical support services for the stewardship of NOAA's assets and infrastructure.

The Amazon Sustainability Data Initiative (ASDI) seeks to accelerate sustainability research and innovation by minimizing the cost and time required to acquire and analyze large sustainability datasets. ASDI supports innovators and researchers with the data, tools, and technical expertise they need to move sustainability to the next level.

Amazon Web Services provides a highly reliable, scalable, low-cost infrastructure platform in the cloud that powers hundreds of thousands of businesses in 190 countries around the world. With data center locations in the U.S., Europe, Singapore, and Japan, customers across all industries are taking advantage of our low cost, elastic, open and flexible, secure platform.

APPENDIX 1: LIST OF ACRONYMS

ASDI — Amazon Sustainability Data Initiative

CODE — Center for Open Data Enterprise

CASC — Climate Adaptation Science Centers

CEQ — Council on Environmental Quality

DOI — U.S. Department of the Interior

EO — Executive Order

EPA — Environmental Protection Agency

FEMA — Federal Emergency Management Agency

GIS — Geographic Information Systems

NOAA — National Oceanic and Atmospheric Administration

RISA — Regional Integrated Sciences and Assessments

SDOH — Social Determinants of Health

USDA — U.S. Department of Agriculture

APPENDIX 2: CLIMATE DATA STAKEHOLDERS AND THE DATA VALUE CHAIN

CODE drafted a Stakeholder Analysis and Data Value chain that analyzes the various stages of the climate risk data production process, from observation all the way to assessment, and the various stakeholders who are responsible for their production. This analysis is intended to explain how data is produced in the climate risk sector and who is responsible for its collection, sharing, analysis, and stewardship.

Roundtable on Data for Climate Risk Assessment in Vulnerable Communities
Data Pipeline Stakeholder Analysis

CLIMATE RISK DATA STAGE	STAGE OVERVIEW	SUPPORTING STAKEHOLDER GROUPS	EXAMPLE STAKEHOLDERS
Observation and Collection *New observational data gathered manually from humans or automatically through sensors and satellites.*	Climate observations form the basis of climate risk data, and may include hydrological, geophysical, meteorological, biological, or climatological data. This data can be gathered through satellite imagery, direct human observation, or through sensors or instruments, especially with hydrological or geophysical climate observations. For example, NOAA's Climate Reference Network carefully monitors precipitation levels and average temperatures through a series of 114 observation stations around the country.	*Government agencies* produce the majority of publicly available datasets through observation stations, satellites, and automated sensors. *Private sector companies* will carry out their own data gathering to measure climate effects and can manufacture instruments that measure climate variables. *Clvil Society and citizen scientists* document biological phenomena, climate events or other climatological attributes. They often log important climate-related observations through online platforms and provide helpful analysis to communities with lower financial capacity.	• U.S. Climate Reference Network • United States Geological Survey • Thermometrics Corporation • CitSci.org • Citizen Science Monitoring in the Carolinas • Planet Labs

CLIMATE RISK DATA STAGE	STAGE OVERVIEW	SUPPORTING STAKEHOLDER GROUPS	EXAMPLE STAKEHOLDERS
Quality Control and Input *The entry of valid climate risk observational data into a storage system. Can be done manually or automatically.*	Recorded observational data must pass an initial stage of data quality assurance and validation prior to further processing. Observers will validate that the observations are scientifically possible and potentially make adjustments to their instruments if errors are discovered. Data will then be submitted to a center or online site for further review.	*Government agencies* utilize scientists and other contractors to input observational data into centralized warehouses and carry out quality assurance. *Private sector* companies can provide external vetting and consulting services to measure the quality of data gathered from the field. *Research centers* in regions across the country also evaluate the quality of their observations, including regional ocean partnerships and ocean observatory systems.	• NOAA's National Weather Service • Trinity Consultants • Environmental Protection Agency • Regional Ocean Partnerships
Processing *Raw data that has been entered is then manipulated and computed before being saved in a specific file format.*	The processing stage usually involves submitting raw data and conducting quick computational statistics, such as taking the mean temperatures from a series of temperature observations. For climate risk data, data managers may also seek to identify maximum and minimum temperatures as outliers, or examine other descriptive statistics. Additional automated processing may provide further quality control by checking for patterns in each record such as spikes, flatliners, outliers, excessive ranges, and change points.	*Government agencies* like BOEM and DOE provide oversight and guidance in data processing and can quickly transform data collected at observation stations into descriptive statistics. *Private sector* companies such as big data firms and web services regularly process raw data and support government agencies with understanding their various data streams.	• Bureau of Ocean Energy Management • Department of Energy • The EPA's Environmental Information Exchange Network • ScienceSoft

CLIMATE RISK DATA STAGE	STAGE OVERVIEW	SUPPORTING STAKEHOLDER GROUPS	EXAMPLE STAKEHOLDERS
Storage and Archiving *Processed information is shared and stored in various locations like data lakes or data containers.*	After processing and data cleaning, much of the processed climate data is then stored on servers and cloud locations for access by different stakeholders. Data access may be based on the user group, with some datasets being published to publicly available websites and other datasets restricted. Practitioners will also include metadata, data dictionaries, and other relevant tags during this phase.	*Private sector companies* like Google and Amazon Web Services are active in providing cloud storage solutions for climate risk data. *Government agencies* may work directly with private sector contractors to store and archive data, especially datasets that are not as requested by researchers, policymakers, or civil society groups.	• NOAA's Big Data Program • CyrusOne Data Centers • Amazon Web Services
Publishing and Products *Data is published either through data visualization or packaged into products for use by industry in sectors like real estate, energy, and agriculture.*	Following the storage and archiving phase, data may be published in large file formats or further developed by stakeholder groups to create additional products. These data products can include geospatial products that map out potential climate risks, risk-specific tools such as flood-scores, and company-based risk metrics to help private industry prepare for climate risks.	*Private sector companies* like insurance or risk-based firms may combine climate data from government agencies or other contractors with their own data to create tailored products for clients. *Geospatial Consulting Firms* like Esri and MySidewalk may take purchased or public datasets and develop geospatial solutions for easy customer use.	• MySidewalk • Esri • RenaissanceRe • Moody's Climate Solutions • Jupiter Intelligence • Rhodium Group

CLIMATE RISK DATA STAGE	STAGE OVERVIEW	SUPPORTING STAKEHOLDER GROUPS	EXAMPLE STAKEHOLDERS
Application and Analysis After data is processed, stored, and published in online portals, it can be applied and analyzed by a variety of stakeholders.	After data is published and products are accessible, data may then be used by a wide range of stakeholders to test hypotheses, design or evaluate municipal policies, adjust business models, and generally forecast major climate risks. These stakeholders will often produce reports and outline potential risks based on data observations. These groups may also integrate other climate-relevant data, such as socioeconomic data or the social determinants of health, to bolster their analyses. For example, the First Street Foundation uses decades of readings from NOAA's tidal gauge stations to identify regular tidal variations, storm surges, and long term sea level rise trends.	*Cities and municipal governments* like Boston and Pittsburgh have used climate tools and datasets to develop comprehensive Climate Action Plans and Climate Ready strategies to address potential risks. *Private Sector* companies in impacted sectors such as agriculture, real estate, and manufacturing may purchase third party climate risk products and tools to integrate these outlooks into their environmental, social, and corporate governance frameworks. *Civil Society and Advocacy Groups* like First Street Foundation and the World Resources Institute will take either raw data or applied data products and conduct analysis for research and reporting. *Academic Researchers* may leverage online geospatial tools or publicly available products to test areas of climate risk and how they impact vulnerable communities.	• Eagle Rock Analytics • First Street Foundation • City of Pittsburgh • City of Boston • United States Department of Agriculture and U.S. Forest Service • World Resources Institute

CLIMATE RISK DATA STAGE	STAGE OVERVIEW	SUPPORTING STAKEHOLDER GROUPS	EXAMPLE STAKEHOLDERS
Assessment and Revision Data used by the field may be adjusted to better fit expectations and uses by industry, government, and civil society.	Following the application and revision phase, practitioners will provide feedback and suggest revisions to datasets based on data gaps or challenges faced. This may include improvements to the data quality, such as data standards, data sharing, or broader data integration. Or this assessment may identify data gaps or missing datasets at the local level.	*Local Community Groups* may recognize gaps in existing climate risk data or suggest new datasets that would be effective for understanding vulnerabilities of low-income or minority groups with lower economic capacity or social agency. *Civil Society and Professional Associations* such as the American Society of Adaptation Professionals, will provide important insights into data standards or data issues in the climate risk space. *Academic Researchers.* This group will publish emerging research that will underscore limitations of existing datasets and potential improvements for the climate risk data sector.	• Justice40 • MetroLab Network • American Society of Adaptation Professionals • University of Washington's Climate Impacts Group

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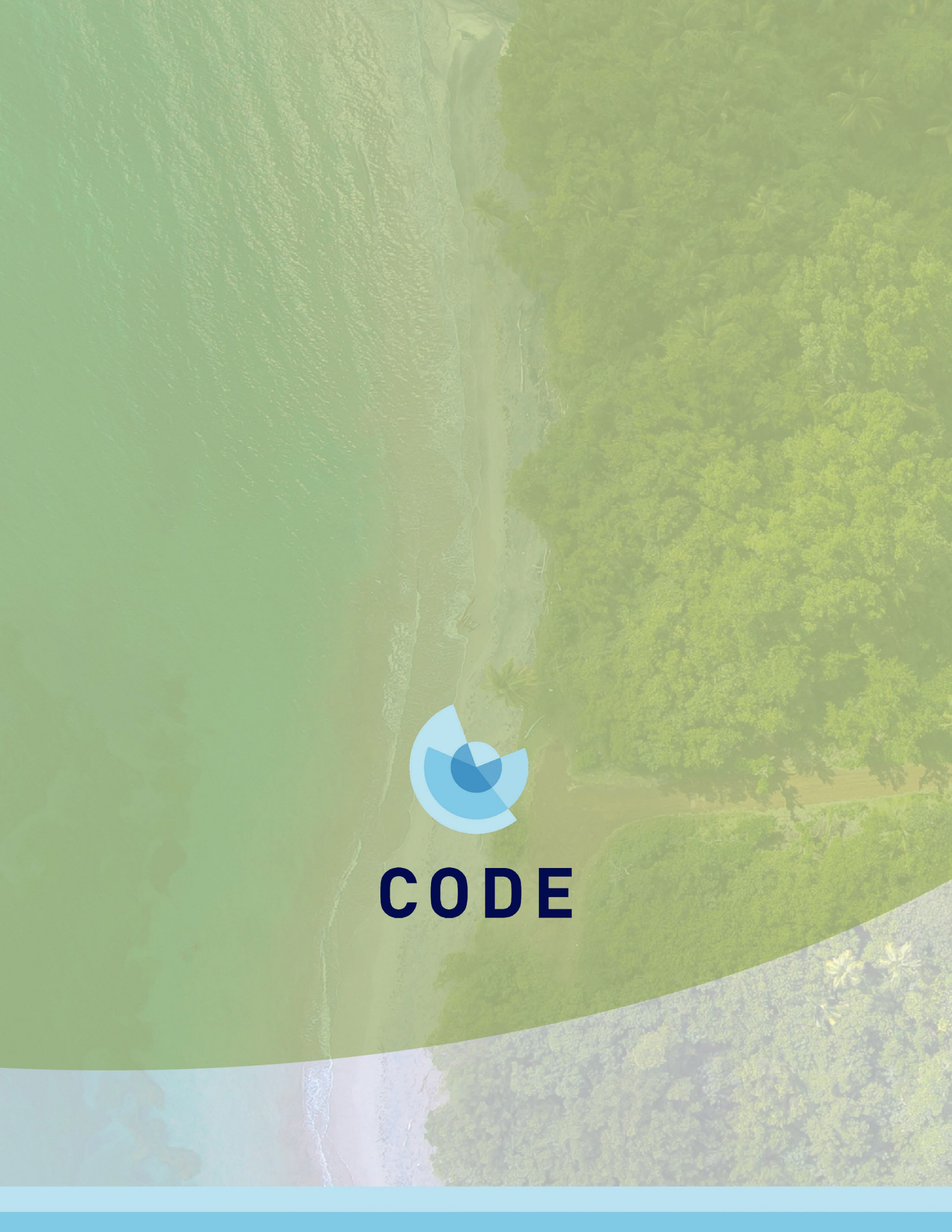

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