Inclusive Climate Resilience Strategies in the US:

Lessons from low- and middle-income countries

July 2022

The GSMA is a global organisation unifying the mobile ecosystem to discover, develop and deliver innovation foundational to positive business environments and societal change. Our vision is to unlock the full power of connectivity so that people, industry and society thrive. Representing mobile operators and organisations across the mobile ecosystem and adjacent industries, the GSMA delivers for its members across three broad pillars: Connectivity for Good, Industry Services and Solutions, and Outreach. This activity includes advancing policy, tackling today's biggest societal challenges, underpinning the technology and interoperability that make mobile work, and providing the world's largest platform to convene the mobile ecosystem at the MWC and M360 series of events.

We invite you to find out more at **gsma.com**
Follow the GSMA on Twitter: **@GSMA**

Central Insights Unit

The Central Insights Unit (CIU) sits at the core of The GSMA Mobile for Development (M4D) and produces in-depth research on the role and impact of mobile and digital technologies in progressing sustainable and inclusive development. The CIU engages with public and private sector practitioners to generate unique insights and analysis on emerging innovations in technology for development. Through our insights, we support international donors to build expertise and capacity as they seek to implement digitisation initiatives in low-and-middle income countries through partnerships within the digital ecosystem.

Contact us: **centralinsights@gsma.com**
Follow us on Twitter: **@GSMAm4d**

Foreign, Commonwealth
& Development Office

This initiative has been funded by the UK's Foreign, Commonwealth and Development Office and is supported by the GSMA and its members. The views expressed do not necessarily reflect the UK Government's official policies.

Authors:
Sone Osakwe (GSMA Mobile for Development), Mike Klein (ITAD), Sarah Miller (ITAD), Gil Yaron (ITAD), Kayla Sainati (ITAD) and Clara Aranda (GSMA Mobile for Development)

Contributors:
Olly Parsons (GSMA Mobile for Development), Daniele Tricarico (GSMA Mobile for Development),
Florence Chaverneff (FCDO/Science and Innovation Network) and Nicolas Hooper (FCDO/Science and Innovation Network)

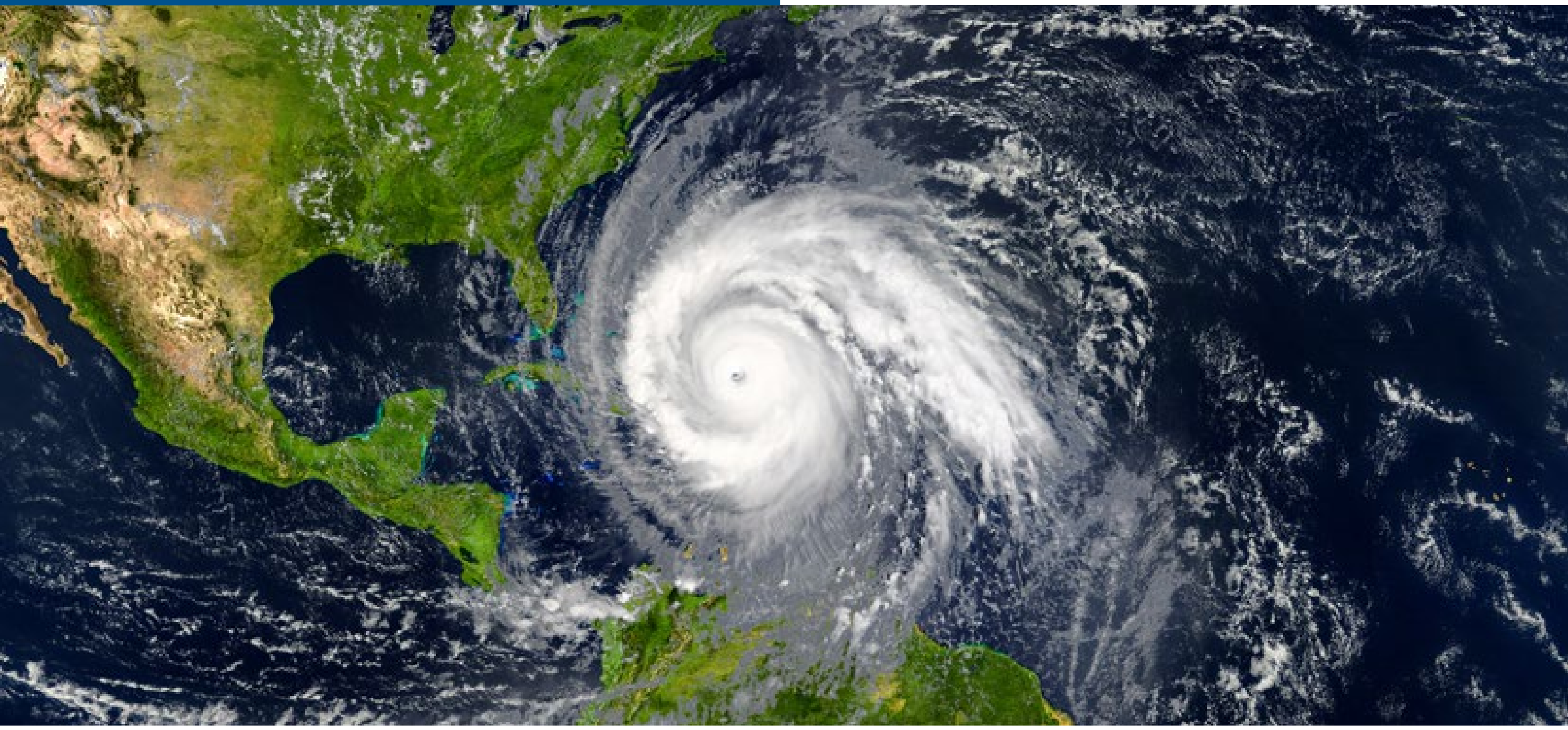
Acknowledgements:
This report draws on research conducted for the GSMA by ITAD Ltd. We would like to thank the many experts and stakeholders who shared their insights with us. Please see the full list of contributors at the end of this report.

Contents

Acronyms and abbreviations

AI	Artificial Intelligence
CASR	Center for Arctic Security and Resilience
CHANTER	Communities in Haiti Access New Technologies for Early Warning/ Response
DEWN	Disaster and Emergency Warning Network
EAS	Emergency Alert System
EPA	Environmental Protection Agency
EWS	Early Warning System
FEMA	Federal Emergency Management Agency
IPAWS	Integrated Public Alert and Warning System
IVR	Interactive Voice Response
LMICs	Low- and Middle-Income Countries
MNO	Mobile Network Operator
NCA	National Climate Assessment
NCRMP	National Cyclone Risk Mitigation Project
NWS	National Weather Service
SMS	Short Message Service
SVI	Social Vulnerability Index
THIRA	Threat and Hazard Identification and Risk Assessment
UMICs	Upper Middle-Income Countries
USGCRP	US Global Change Research Program
WEA	Wireless Emergency Alert

List of figures



Executive summary

Climate-related hazards are on the rise in the US

Climate-related risks and hazards are having significant and diverse economic and social impacts in the United States. With climate zones ranging from coastal tropical to tundra, the types of climate hazards and risks affecting the country are equally varied. In terms of severity and recorded devastation, tropical cyclones, severe storm surge, wildfires, drought and flooding appear to be the most prevalent hazards. In 2021 alone, there were at least 20 climate-related disasters across the US, with more than 680 lives lost and an estimated economic impact of more than $145 billion. These costs included physical damage to buildings and material assets within damaged residential and commercial buildings, losses from the disruption of business operations, public infrastructure damage and disaster suppression costs, among others.

A deeper look at two regions of the country reveals different lived experiences of climate risks. In the Southeast, communities have historically experienced disasters such as coastal flooding and hurricanes. These are worsening and will require more concerted disaster resilience efforts. In Alaska, although climate risks might be considered less imminent, there has been a precipitous rise in risks as temperatures increase and glaciers and permafrost continue to melt (the Arctic region is warming faster than anywhere else in the world). Residents of Alaska need to start planning to mitigate these risks, which are forecasted to have far-reaching impacts in the years ahead and require significant adaptation strategies.

Socially vulnerable groups are the most affected by climate-related risks and disasters

The characteristics of a community or group influences disaster preparedness and response capacity. In the US, minority groups are disproportionately at risk. For instance, Black Americans are 40 per cent more likely than non-Blacks to live in areas where climate change is projected to cause the highest increases in mortality.[1]

Early warning systems at the community level are not as robust as national systems

Multi-hazard early warning systems (EWS) in the US are well developed, but implementing accessible solutions is a challenge, especially for rural and marginalised communities. Across the US, national, state and local authorities use tools such as the Integrated Public Alert & Warning System (IPAWS), as well as state or local solutions ranging from highway signage to emergency television broadcasts. By subscribing to one of the third-party alert origination software providers that are compatible with IPAWS, state and local authorities can issue their own IPAWS alerts and send messages via SMS, phone call or e-mail to residents who opt in. While these systems have the option to access sophisticated features, they are often expensive and beyond the means of many small communities. This suggests there is scope for a more holistic approach that supplements existing EWS with localised solutions and enhances EWS communication for marginalised populations.

1 Environmental Protection Agency (EPA). (2021). Climate Change and Social Vulnerability in the United States: A Focus on Six Impacts.

There are opportunities to improve how emergency warnings are issued and disseminated

Several cross-cutting gaps were identified in EWS in the US. These gaps reflect issues with how the federal alert and warning system is administered and functions at the community level, namely, the inability of local authorities to properly manage or access these systems. Issues include: (1) technology challenges such as message overreach and lack of mobile coverage; (2) equipment that is not user friendly (the communities we consulted find the IPAWS technology quite cumbersome and designed to be managed by a team, not a community volunteer); (3) high costs of training and equipment maintenance; and (4) language barriers for non-English and Spanish speakers.

The US also faces significant cultural challenges related to warnings about climatic and other risks. Americans tend to opt out of mobile notification systems if they find the messages irrelevant or do not understand the messages.[2,3,4] A multi-pronged effort to address system and cultural issues is therefore critical. For example, launching community-led messaging systems with personalised messages for members.

Innovative community-based EWS in low- and middle-income countries offer lessons for the US

Many innovations in low- and middle-income countries (LMICs) employ low-cost technologies and are co-designed with community members. This approach makes it more feasible to adapt solutions that can reach vulnerable populations, especially those in remote areas.

In the US, however, many of the EWS tools are developed using a top-down approach. Combining existing EWS with solutions tailored to community needs can strengthen disaster resilience.

Our research identified solutions in LMICs that could be applied in the US. Examples include CHANTER in Haiti, DEWN in Sri Lanka, AtmaGo in Indonesia and Ushahidi in Kenya. Most of these are cost-effective, mobile-based tools and solutions that communities can use to amplify messages about disaster preparedness and response and reach millions of people. They also offer an inexpensive way to collect localised data that can be used to personalise messages for community residents. This is significant because message recipients are more likely to respond when they feel that messages are relevant to them and can be verified by multiple sources or channels.

2 Bean, H. et al. (2016). "Disaster Warnings in Your Pocket: How Audiences Interpret Mobile Alerts for an Unfamiliar Hazard." Journal of Contingencies and Crisis Management, 24, pp. 136–147.
3 Bean, H. and Botterell, A. (2019). Mobile Technology and the Transformation of Public Alert and Warning. Santa Barbara, California: Praeger Security International.
4 Bennett, D.M. (2015). Gaps in Wireless Emergency Alert (WEA) Effectiveness. Public Administration Faculty Publications.

01

Introduction

As climate-related weather events become a greater risk across the globe and in the United States, innovative and inclusive early warning systems (EWS) are critical to mitigate these risks and strengthen preparedness for climate disasters. The frequency and impact of climate-related events have escalated in the US in recent years, negatively impacting communities and resulting in loss of life, property and livelihoods.

142

weather- and climate-related disasters costing **at least $1 billion each** have been recorded in the US in the past 10 years

Estimated cumulative cost of these events between 2012 and 2022 was more than

$1 trillion

Most common and costly events:

- Hurricanes
- Cyclones
- Wildfires

Sources: NOAA[5]

5 NOAA National Centers for Environmental Information (NCEI). (2022). Billion-Dollar Weather and Climate Disasters 2022.

Planning for climate change requires that government institutions and local communities adapt and prepare systems and strategies to mitigate the risks of climate-related disasters and build their resilience and capacity to respond. Such strategies include setting up advanced EWS to collect data and monitor potential disasters, conduct predictive analysis and issue warnings, disseminate information about risks to communities and improve national and community response capabilities. Early warnings that alert people to imminent climate risks and events can empower at-risk populations to plan and make decisions to protect lives and livelihoods. While there is a robust national model for assessing, monitoring and warning against climate risks at federal and state levels in the US, there appears to be less consistency and reliability at the local county level.

One crucial issue that is frequently overlooked in an emergency context is inclusion. Minority groups and marginalised communities, which already experience inequalities, are the most affected by climate change. For instance, in the US, these groups are more likely than any other to live in areas prone to flooding.[6] More inclusive and people-centred systems and strategies are critical to having a greater impact on the ground. In terms of warning alerts or messaging, this could mean translating messages into different languages and using various channels to ensure they reach diverse audiences. The importance of this became clear during Hurricane Ida in New York in 2021 when at least 11 immigrants drowned in their basement apartments due to language barriers in understanding warning messages.[7]

Climate risks and creating systems to mitigate them are a global challenge. Governments, stakeholders and communities in low- and middle-income countries (LMICs) are making significant investments in EWS, including in systems that rely on new technologies and innovations that may be replicated in the US context and other upper middle-income countries (UMICs). LMICs are at the forefront of innovative and inclusive EWS, creating new systems rather than modifying or replacing existing ones, and tailoring them to the needs of economically and socially diverse communities.

It is important to note that while this report focuses on technologies being used in LMICs, many communities and organisations in the US are already using similar technologies, with varying degrees of success. Some US states have implemented laws addressing issues like language gaps in EWS,[8],[9] but these states are not the focus of this report. Meanwhile, the federal government has provided extensive guidance on communication with limited English-speaking populations,[10] and conducted a comprehensive review of gaps in current EWS[11] and proposed new rules for the Emergency Alert System (EAS).[12] The intent of this report is therefore to build on the work already underway in the US, specifically in the Southeast and Alaska, and to learn from successful examples of disaster resilience and digital technology in LMICs that could be transferable to the US context, especially at the community level.

6 EPA. (2021). Climate Change and Social Vulnerability in the United States: A Focus on Six Impacts.
7 Venkatraman, S. and Yam, K. (2021). "They Had to Make Homes of Illegal Basement Apartments. Ida's Surge Killed Them". NBC News.
8 Emergency Management Division of Washington Military Department. (2018). LEP Communication Planning Framework, Version 1.0.
9 California Governor's Office of Emergency Services (Cal OES). (March 2019). State of California Alert and Warning Guidelines.
10 Federal Coordination and Compliance Section, Civil Rights Division, U.S. Department of Justice. (2019). Tips and Tools for Reaching Limited English Proficient Communities in Emergency Preparedness, Response, and Recovery.
11 The Communications Security, Reliability and Interoperability Council. (2018). Final Report: Comprehensive Re-imagining of Emergency Alerting.
12 Federal Communications Commission (FCC). (2021). "Amendment of Part 11 of the Commission's Rules Regarding the Emergency Alert System", FCC-CIRC2112-01.

1.1 Research objectives

This report identifies gaps in EWS for climate-related hazards in the US, and reviews mobile and digital solutions in LMICs that could help improve EWS for underserved and vulnerable communities in the US. Innovations related to the use of mobile and frontier technologies in EWS, including mobile-enabled services from phone calls, SMS, cell broadcast systems, the application of big data, artificial intelligence (AI) and machine learning, sensors and 5G, among others, fall within the scope of this research.

This report aims to:

- Characterise and identify gaps in EWS for climate hazards in the US, with a focus on two regions;
- Identify examples of technological interventions in LMICs for community-based EWS that help marginalised and underserved groups become more resilient to climate-related disasters; and
- Based on use cases from LMICs, map the gaps in EWS systems in the US to provide recommendations for strengthening EWS.

2.1 Methodology

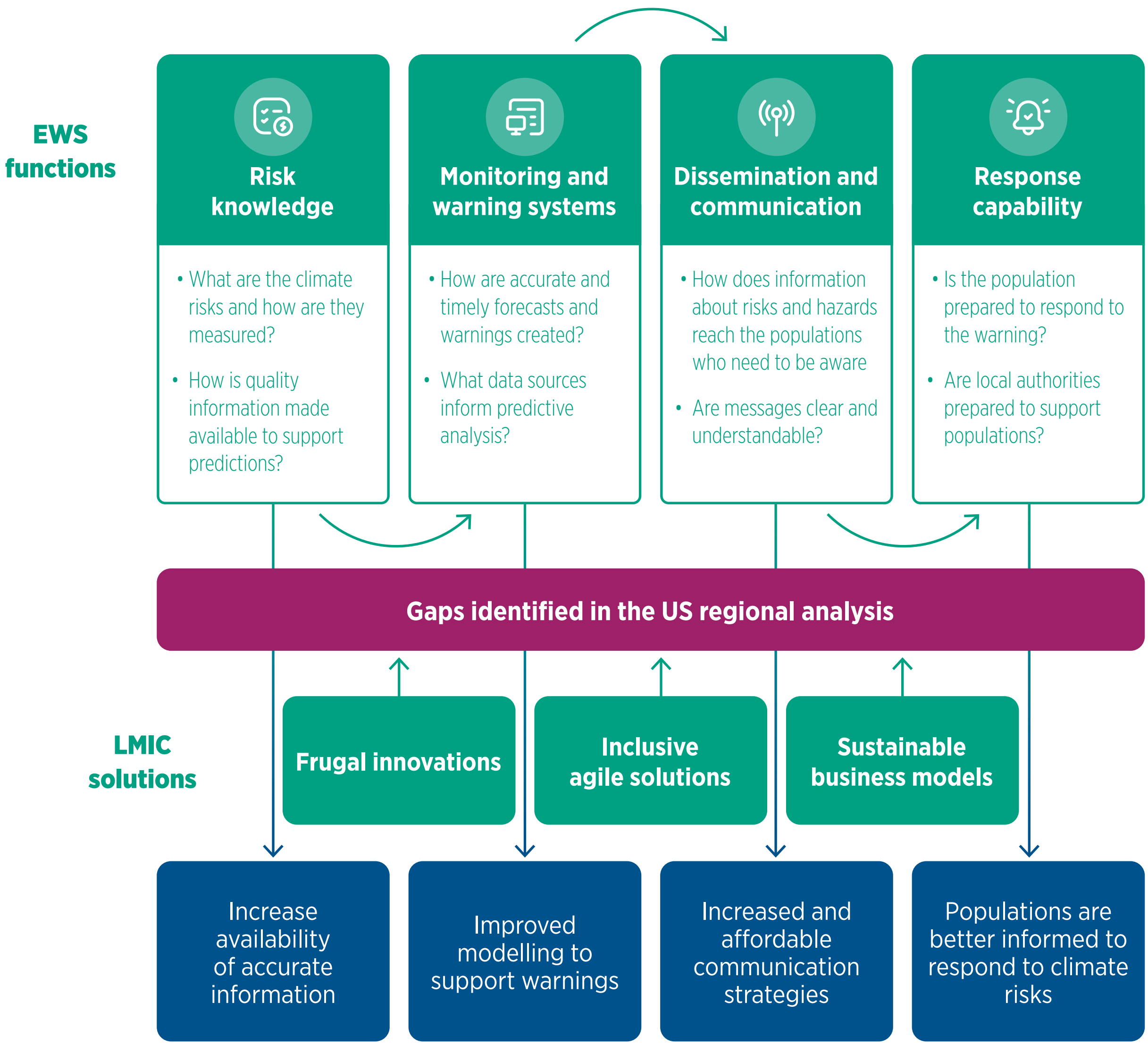
This research will support wider efforts in the US to build climate- and disaster-resilient communities through innovation and technology. A qualitative approach was taken to achieve these objectives. Findings were uncovered through extensive literature reviews, case studies and semi-structured interviews with 20 local stakeholders in the US and 5 international stakeholders involved in EWS in LMICs. A full list of participants in our key informant interviews can be found in Annex 1.

A two-pronged approach was used to select two US regions for further investigation. First, we assessed regions with high frequency and severity of climate hazards, as well as high levels of social vulnerability. We found that communities in the Southeast and Alaska are experiencing climate disasters differently, which provided a range of issues to analyse and discuss.

In the Southeast, communities are coping with climate disasters that are becoming more frequent and severe, such as tropical cyclones, and that require more targeted and effective EWS. In Alaska, meanwhile, communities need to start planning for climate risks that are forecasted to increase and have far-reaching impacts, and find ways to adapt, including developing new EWS using digital technologies. Since the geographical scale of these regions makes it challenging to capture the full range of EWS capabilities and limitations, six counties were selected for data collection: four in the Southeast and two in Alaska (see descriptions in section 3).

To explore the feasibility of transferring and adopting technologies developed in LMICs in UMICs, the study uses a guiding framework (see Figure 1) informed by the EWS model that was developed by the United Nations Office for Disaster Risk Reduction (UNDRR). The framework divides EWS functions into four components: (1) risk knowledge systems; (2) monitoring and warning systems; (3) dissemination and communication systems; and (4) response capability systems. While risk knowledge systems generate information related to climate risks, monitoring and warning systems translate the source information to identify the magnitude of a climate risk. Dissemination and communication systems communicate the risk to the population, and response capability systems support communities to respond appropriately. Our framework is also built on three principles: (1) "frugal innovation", which describes technology solutions that are low cost but high impact; (2) agile solutions that work across multiple cultural contexts and are inclusive by design; and (3) sustainable business models.

Figure 1:
Guiding framework for technology transfer from LMICs to UMICs



Source: Authors

02

Overview of climate risks and early warning systems in the US

2.1 Prevalent climate risks and social vulnerabilities

Climate-related risks and hazards are having significant and diverse economic and social impacts in the US. With climate zones ranging from coastal tropical to tundra, the types of climate hazards and risks are equally varied. Figures 2 and 3 depict the growing trend of climate-related disasters and the associated impacts.

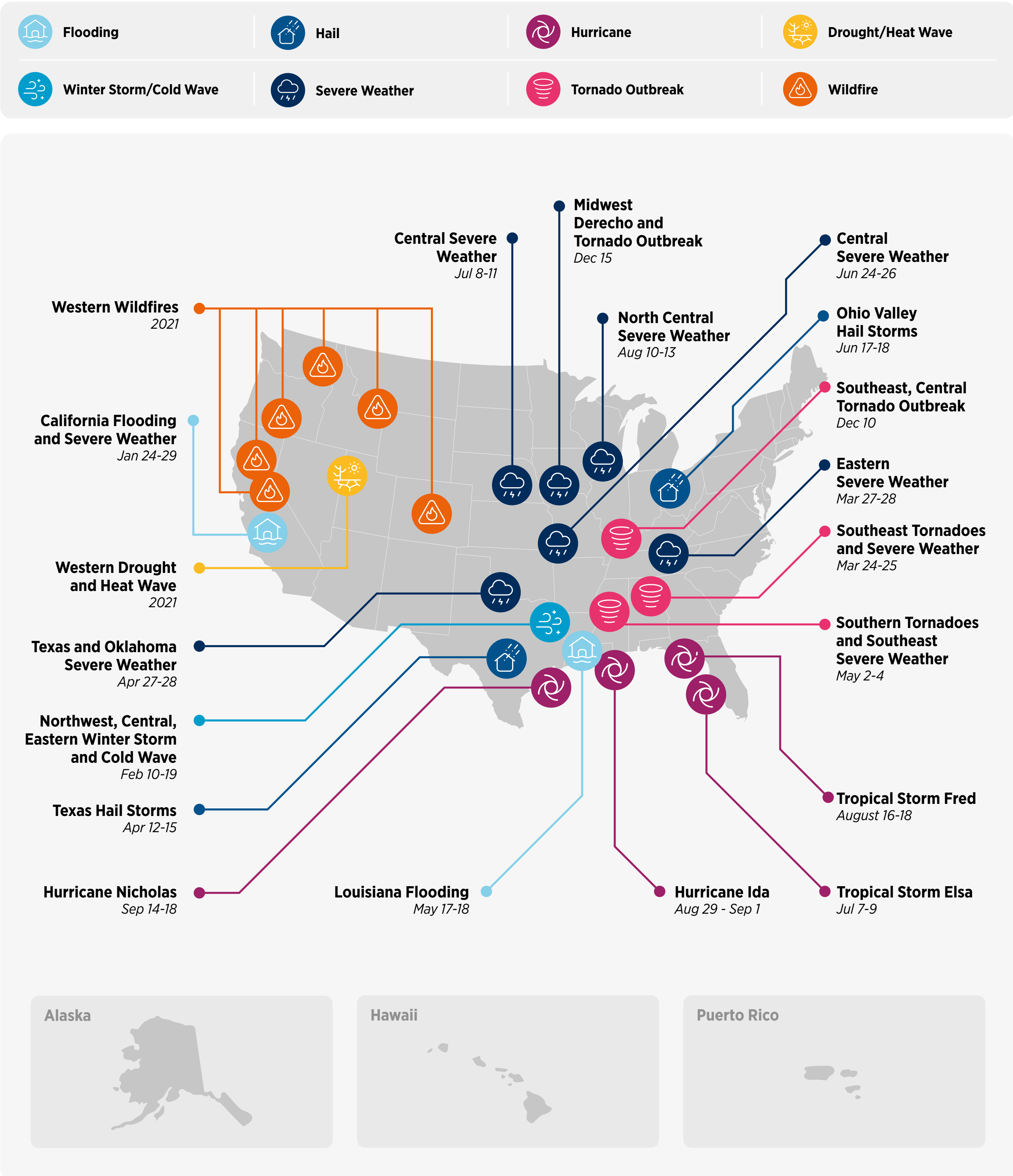
In terms of severity and recorded devastation, tropical cyclones, severe storm surge, wildfires, drought and flooding appear to be the most prevalent hazards in the US. The damage and rehabilitation funds that will be required are infinite. In 2021 alone, there were at least 20 climate-related disasters across the US, with more than 680 lives lost and an estimated economic impact of more than $145 billion. These costs included physical damage to buildings and material assets within damaged residential and commercial buildings, losses from disruption of business operations, public infrastructure damage and disaster suppression costs, among others. In the US, the costs of managing and recovering from these events are split between federal public aid, state public aid, private insurance, private donations and individual resources. As a result, estimating the total cost of a disaster event is largely subjective.

Figure 2:
Costliest climate disasters in the US, 2012–2021[13]

Disaster type	Event frequency	Total costs	Percentage of total costs	Average cost per event	Deaths recorded
Tropical cyclone	21	$577.9 bn	56.9%	$27.5 bn	3,691
Severe storm	82	$175.8 bn	17.3%	$2.1 bn	493
Wildfire	8	$88.3 bn	8.7%	$11.0 bn	258
Drought	9	$83.3 bn	8.2%	$9.3 bn	450
Flooding	16	$56.2 bn	5.5%	$3.5 bn	164
Winter storm	5	$33.8 bn	3.3%	$6.8 bn	303
Freeze	1	$1.1 bn	0.1%	$1.1 bn	0
Total	**142**	**$1.0 tn**	**100%**	**$7.2 bn**	**5,359**

13 NOAA National Centers for Environmental Information (NCEI). (2022). Billion-Dollar Weather and Climate Disasters.

Figure 3:
Worst climate disasters in the US in 2021, by geographical location[14]

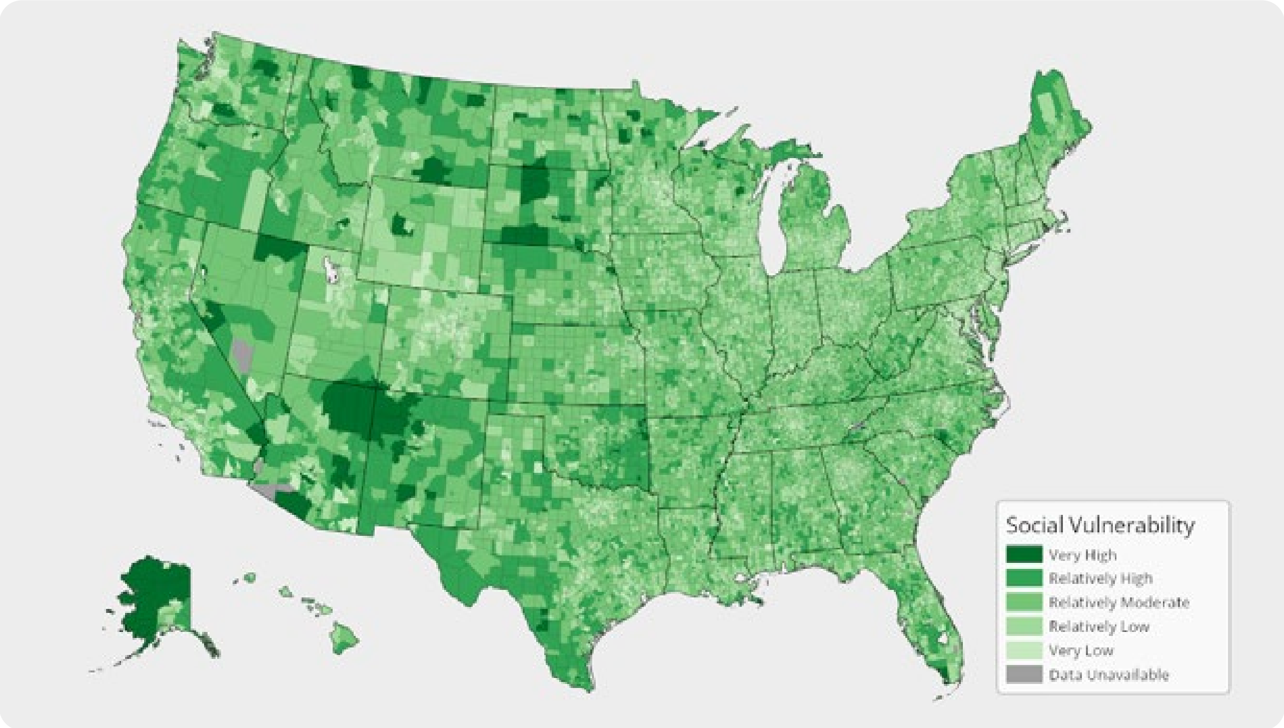


Source: NOAA National Centers for Environmental Information (NCEI)

14 Ibid.

The magnitude of the impact of these kinds of disasters not only depends on the type of climate hazard, but also the vulnerabilities of affected communities and groups. The Social Vulnerability Index (SVI), which measures the social vulnerability of US counties to adverse environmental hazards, identifies the disparate preparedness, response and recovery capabilities of different groups and communities. The variation in social vulnerability stems from differences in community or group characteristics, including wealth status, race/ethnicity, age, special needs or disability, gender and employment, among others. Communities with endemic poverty, high unemployment, low education and poor access to health care typically find it much more difficult to adapt to and return to normal after a climate-related disaster. Data on these variables are used to produce a social vulnerability ranking, as shown in Figure 4.

Figure 4:
Social Vulnerability Index[15]



Source: University of South Carolina Hazards Vulnerability and Research Institute

The map shows that certain parts of the US, such as Alaska, have much more socially vulnerable groups than others, an indication of very low community resilience. A study by the US Environmental Protection Agency (EPA) highlights the degree to which four categories of socially vulnerable groups in the US are disproportionately exposed to climate risks.[16] The categorisation is based on income, education, race and ethnicity and age.

Among these vulnerable populations, the study identifies racial and ethnic minorities as the most at-risk group in the country, with the highest likelihood of living in areas that will be affected by climate risks. For example, Black Americans are 40 per cent more likely than non-Black Americans to live in areas where mortality due to climate change is projected to be highest. Hispanic and Latinx individuals are 43 per cent more likely than non-Hispanic and non-Latinx individuals to live in areas where labour losses due to climate-related increases in high-temperature days are projected to be highest.

15 University of South Carolina's Hazards Vulnerability & Research Institute. "Social Vulnerability Index for the United States 2010–14".
16 EPA. (2021). Climate Change and Social Vulnerability in the United States: A Focus on Six Impacts.

2.2 EWS in the US

The disaster response system in the US is based on a bottom-up model that places responsibility for disaster preparedness, response, recovery and mitigation at the local community level, while much of the country's EWS were developed using a top-down approach. Using the UNDRR's people-centred EWS model, Figure 5 shows how EWS in the US moves from climate risk detection to risk prediction, communication to the public and, ultimately, action.

Figure 5:

US EWS actors and technologies used

		Risk knowledge	Monitoring and warning	Dissemination and communication	Response capability
	Actions	Public and private stakeholders develop emergency preparedness plans and gather data relevant to local risks. FEMA develops national hazard and risk assessments. Thirteen additional federal agencies are charged with climate change research under the US Global Change Research Program (USGCRP).	Authorities ensure alerts are sent through disseminators. Modes of dissemination are regulated and established through federal and state actors.	Authorities send alerts to platforms for dissemination, including EAS, WEA, NOAA, internet services, state and local alerting systems, and via new technologies, including social media. Private partners also disseminate alerts on a variety of platforms.	Alerts are received and acted upon in accordance with established emergency preparedness plans. Most, if not all, states mandate these plans to the local level. Responsibility is linked to the local authorities for planning purposes.
	Tools	National Risk Index, NCA4, NOAA Climate Resilience Toolkit, NWS, local weather and sensor data.	Alert Origination Software Providers (AOSP) with demonstrated alerting capabilities and linked data monitoring solutions, linked closely with the IPAWs system.	IPAWS-approved alerting systems provide outreach via TV, radio, mobile, internet-connected devices (billboards, social media, etc.), sirens and emerging technology. Additional channels include reverse dialling systems, email/SMS groups, etc.	Devolved authority to state and local entities for response. Available tools include Ready, Set, Go! and other community-based response plans.
Stakeholders	Government	FEMA, DHS, NOAA, state, local, tribal and territorial government.	FEMA, NOAA, state, local, tribal and territorial government.	FEMA, state, local, tribal and territorial government.	FEMA, state, local, tribal and territorial government.
Stakeholders	Other actors	Civil society organisations, academic institutions, private corporations, local data providers (e.g. Purple Air, Ambient Weather).	AOSPs including Everbridge, Onsolve, and other monitoring and warning platforms.	Message dissemination system operators (schools, health care systems, etc.), TV and radio operators, mobile networks, mobile app providers, social media firms, electronic media providers, etc.	Whole-of-community response, linked to existing emergency preparedness plans.

Source: Authors

2.2.1 Risk knowledge systems

Risk knowledge is a combination of long-term formal hazard and vulnerability assessments of climate-related risks (conducted primarily by the federal government and spread across numerous agencies) and short-term assessment and evaluation by state or local governments and their partners. The boundaries are not well defined, however, and some states also have long-term risk knowledge capabilities. The National Weather Service (NWS) is authorised by statute to be responsible for issuing most early warnings for multi-hazard and climate-related risks.[17] The NWS has long-term partnerships with other federal agencies, most notably the Federal Emergency Management Agency (FEMA) to leverage their expertise and infrastructure.

FEMA provides guidance and tools through the National Risk and Capability Assessment (NRCA).[18] One such tool is the Threat and Hazard Identification and Risk Assessment (THIRA), a high-level overview that covers the entire nation. At the state and local level, FEMA provides guidance on how to conduct a THIRA, including possible data sources such as federal agencies, public safety organisations, colleges and universities, local records on past events, NWS officers, private sector partners and others.[19] This data is then contextualised for the affected community using census statistics, time of day, demographics and other information, so that the real-life impacts of a potential event can be understood. Depending on the abilities of the organisation conducting the THIRA (such as county emergency management offices), the end product may contain maps, graphs, charts and textual components that help people understand the true nature of the risk.

The US Global Change Research Program (USGCRP), a coalition of 13 federal agencies, also provides long-term climate-risk assessments. The USGCRP Climate Resilience Toolkit (CRT) helps local communities apply climate change-related data to their unique circumstances. The program also coordinates public-private partnerships related to climate change, and catalogues and shares trends and datasets related to climate issues using the Global Change Information System (GCIS) and the periodic National Climate Assessment (NCA) report. The sources of these datasets include satellite, aerial and ground observations, as well as ocean-based mission platforms and networks. More than 200 data sources were used in 2021.

Overall, the US has some of the most advanced and best-in-class systems in the world for the detection of climate risks. These systems provide a comprehensiveness and specificity not available in most geographies. These technologies are hosted across federal and state agencies, as well as by university partners.

17 The NWS has nine centres for specific weather and climate issues and 122 local offices spread across all geographic regions.
18 Department of Homeland Security, Federal Emergency Management Agency. (2019). 2019 National Threat and Hazard Identification and Risk Assessment (THIRA).
19 Department of Homeland Security, Federal Emergency Management Agency. (May 2018). Threat and Hazard Identification and Risk Assessment (THIRA) and Stakeholder Preparedness Review (SPR) Guide. Comprehensive Preparedness Guide (CPG) 201, 3rd Edition.

2.2.2 Monitoring and warning and dissemination and communication systems

In the US, monitoring, warning, dissemination and communication are largely combined, with all levels of government having some responsibility for each piece. While monitoring and communicating climate-related threats is handled at the federal level, state and local jurisdictions must be prepared to receive those warnings from NWS, contextualise them and relay or rebroadcast them to their local communities, along with specific protective measures that must be taken, such as evacuation or shelter-in-place messages. Monitoring and unofficial warnings are also conducted by many private companies that have access to much of the same raw data as the NWS. Academic institutions also play a large role in monitoring climate risks, often using grant funds provided by the USGCRP.

Across the US, national, state and local authorities use the Integrated Public Alert & Warning System (IPAWS) supported by FEMA, and state or local solutions ranging from highway signage to emergency TV broadcasts. IPAWS is the most critical tool for notifying the public of human-induced or natural disasters. More than 1,600 jurisdictions and agencies across the US are authorised by FEMA to send IPAWS messages, which enables EWS messaging to be sent to almost all mobile phones. IPAWS also provides access to other message delivery mechanisms, such as the EAS, digital signage and new outlets, including city kiosks, sirens, critical event management and accessible alerting apps.

While NWS offices or centres have the authority and ability to issue primary alerts and warnings via IPAWS, they cannot issue them to local communities. Similarly, states and local jurisdictions do not have the authority or ability to issue primary alerts and warnings related to most weather risks,[20] but they can issue evacuation notices and enact other protective measures based on NWS alerts. For instance, if the NWS issues a river flood warning, the warning will specify the areas that will be inundated. State and local authorities then amplify the NWS message using multi-channel communication tools, with specific instructions on where people should go, what roads they should avoid and possibly more detailed information about evacuation areas (sometimes even specific addresses).

State and local authorities can have direct access to IPAWS if they apply, are trained, receive authorisation from and purchase a third-party system to generate alerts and maintain a monthly testing schedule. By subscribing to one of 28 alert origination software providers (private companies) that are compatible with IPAWS,[21] state and local authorities can issue their own IPAWS alerts to mobile phones, covering everything from civil emergencies to evacuations.[22] Many of these systems also provide an opt-in feature, giving subscribing jurisdictions the ability to send messages related to emergencies via SMS, phone call, app alerts or e-mail to community members who have opted in. These technologies increase the availability of critical information, such as translating life-saving messages into multiple languages. Adding more sophisticated features is expensive, however, and beyond the means of many small communities. A basic IPAWS subscription to send out alerts costs $1,000 per year for authorised message senders (state, local, tribal and territorial governments), but no additional features are included.[23]

Every state in the US currently has at least one authorised alerting authority through IPAWS, while 45 per cent of US counties have similar access. Where local communities do not have direct access to IPAWS, the state can issue IPAWS messages on their behalf. Small communities also use other alerting channels, such as social media, phone calls and even sirens to communicate warning information.[24]

20 Except for wildfires.
21 FEMA. (2022). "Alert Origination Software Providers".
22 In this report, we refer to climate-related alerts/warnings from state or local authorities as secondary alerts for clarity.
23 See: https://www.onthegoalerting.com/faqs
24 Refer to Annex 3 for an illustration of how alerts are distributed through IPAWS.

2.2.3 Response capability

Response capability varies widely from city to city and state to state. Some jurisdictions have strong response capabilities while others have much less. Part of the THIRA assessment (see section 2.2.1) is establishing capability targets for each identified hazard, then comparing them to existing local capabilities to identify gaps. When the assessment is conducted properly, communities will understand the gaps they might experience in any given event and can begin working to fill that gap, either with local resources or by planning in advance for mutual aid.

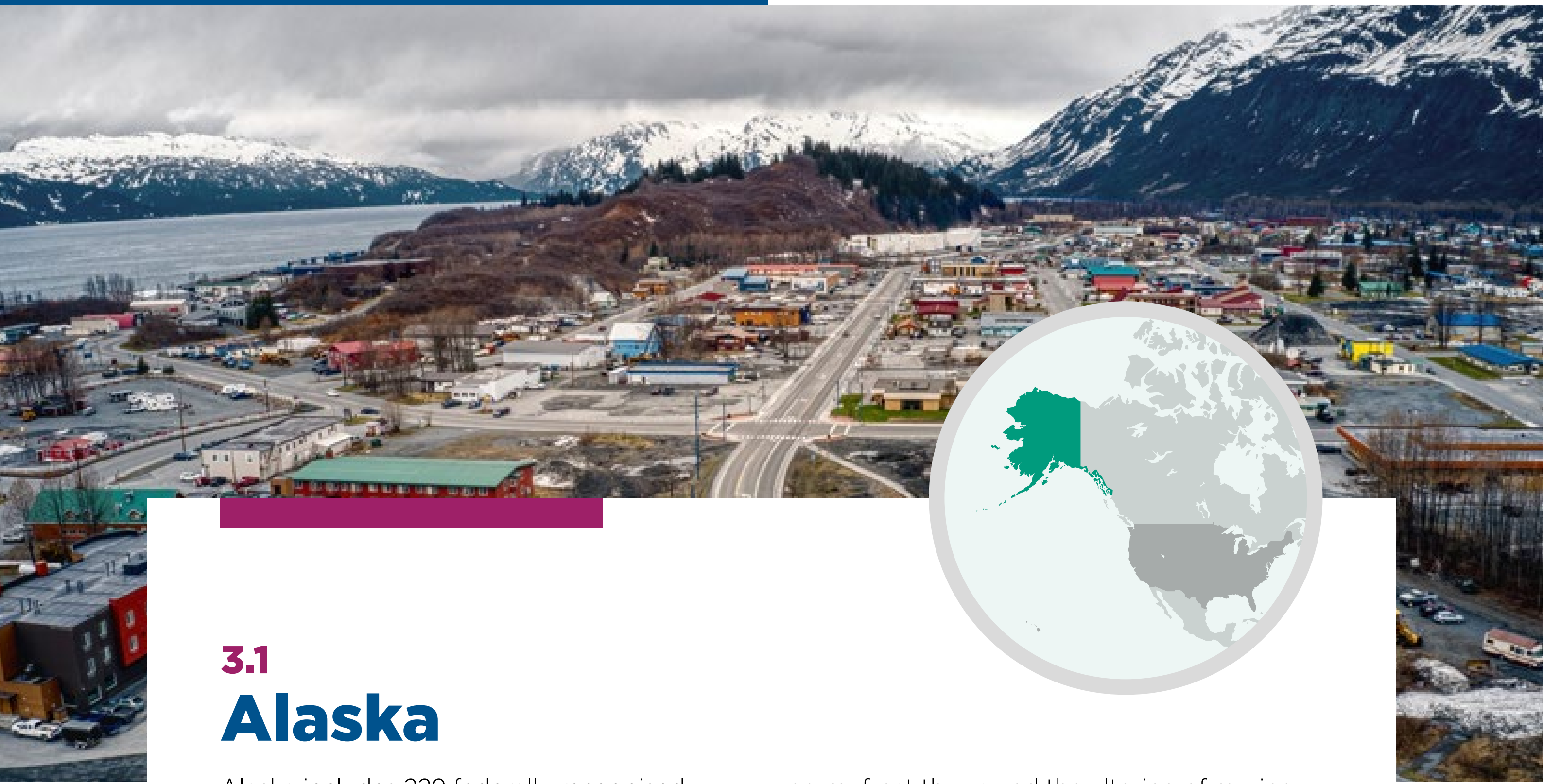
Mutual aid systems are in place at various levels of government and allow resources to be sent from one government jurisdiction to another. Communities generally turn to in-state mutual aid when an incident is too severe to handle themselves, but in remote areas this can be a lengthy process. The US also has an extensive interstate mutual aid system called the Emergency Management Assistance Compact (EMAC),[25] which gives every state in the country the ability to share government resources across state lines. It also allows cities and counties to access resources from other states if they can pay the associated costs.

25 EMAC website: https://www.emacweb.org/

03

Climate hazards and risk profiles of two US regions

Although different geographic regions experience different climate threats, the interconnectedness of climate hazards and the systems people rely upon make it nearly impossible to single out one climate threat as the most devastating or risky. This section provides a snapshot of the climate risks, impacts and disaster preparedness strategies in place in Alaska and the Southeast. The Southeast provides an example of communities that have consistently been exposed to major climate catastrophes, while exposure to severe climate hazards in Alaska are less imminent but forecasted to have devastating effects.



3.1
Alaska

Alaska includes 229 federally recognised tribes, representing more than 20 cultural groups and distinct native languages.[26] Much of Alaska is accessible only by air or sea, and many Alaskan native villages and communities still lack amenities such as sewer and water systems and other critical infrastructure that is generally taken for granted elsewhere.[27] The region is highly dependent on its abundance of natural resources, including mining, oil and fishing, much of which is exported to other states and countries. The state also depends on tourism activities.

As part of the Arctic region, Alaska is on the front line of climate change, warming twice as fast as the global average and faster than any region on earth.[28] These fast-warming conditions are affecting every aspect of life and increasing the likelihood or occurrence of several climate-related hazards. Alaska has not experienced the "billion-dollar" climate-related disasters that have struck other parts of the US, but without adequate mitigation plans, in the coming years the state is very likely to experience phenomena such as glacier melt, permafrost thaws and the altering of marine ecosystems. The most recent NCA report identified the following forecasted impacts:[29]

- Ground sinking (subsistence) results in threats to existing infrastructure and construction, as well as the loss of archaeological sites, structures, objects and cultural properties of Alaska's Indigenous peoples.
- Ocean acidification affecting marine and mammal habitats and the survival of fish and crab species important for personal and commercial use as a result of melting icebergs and sea ice.
- Increased storm surge, coastal flooding and erosion, leading to a loss of shorelines and forcing communities to relocate due to reduced sea ice.
- Accelerated erosion, increased landslides and, in some cases, flooding as a result of glacial shifts and changes. These changes also produce uncertainties for hydrologic power generation, an important Alaskan resource.

26 U.S. Department of the Interior, Indian Affairs, Alaska Region: https://www.bia.gov/regional-offices/alaska
27 Alaska Water and Sewer Challenge (AWSC): https://dec.alaska.gov/water/water-sewer-challenge/
28 Clement, J.P., Bentson, J.L. and Kelly, B.P. (2013). Managing for the Future in a Rapidly Changing Arctic: A Report to the President. Interagency Working Group on Coordination of Domestic Energy Development and Permitting in Alaska.
29 U.S. Global Change Research Program (USGCRP). (2018). Fourth National Climate Assessment.

The financial cost of Alaska's warming climate is projected to be huge, ranging from $3 billion to $6 billion (in 2015 dollars) between 2008 and 2030. However, the human impacts, from food security to culture and health, are arguably greater. The impacts will likely vary between on-road and off-road communities.[30] A report from the University of Alaska Anchorage estimates some of the most certain consequences of climate change will cost the state between $340 million and $700 million per year over the next three to five decades.[31]

Marginalised groups disproportionately affected by climate hazards

The Indigenous population of Alaska is proportionally the highest of any US state, at just over 15 per cent. According to studies by the EPA, Alaska natives are 48 per cent more likely than other groups to live in regions with the most land at risk of disappearing beneath sea water. Having survived thousands of years in this harsh climate, Alaska native peoples, more than any other time in their history, are encountering forces that undermine their cultural survival and way of life. Traditions such as fishing, hunting, food preservation and their ancestral knowledge of the land and native practices are threatened or quickly becoming irrelevant as the Alaskan landscape morphs into something new and unfamiliar. As one Indigenous elder of Kotzebue explained, "We've had to modify our way of hunting and we've also had to become very, very, careful. The last two years I have not hunted in the spring because it has become so different that I don't want to lose my life because you cannot read the ice as well as we used to. The way of reading the ice is no longer valid. It has changed so much."[32] These climate changes are making people in Alaska vulnerable to health-related illnesses, threatening their food and water security and contributing to the loss of ancestral knowledge, culture, legacy and way of life.

Existing EWS mechanisms for major hazards and risks

Incorporated communities (towns or cities with recognised boundaries and some form of local government) in Alaska generally have hazard mitigation plans, which include detailed hazard and vulnerability analysis. The plans follow a somewhat scripted format provided by FEMA, and in Alaska, many local communities are supported in their planning efforts by the Center for Arctic Security and Resilience (CASR), as well as the state government. Data for the plans come from a variety of sources, including local, state and federal government agencies. The assessment of that data is carried out in a variety of ways, from the use of FEMA's free GIS-based software to conversations with community partners. Local residents typically have a good understanding of the risks in their community based on both official communication and traditional knowledge. Traditional knowledge is becoming less useful, however, as risks shift due to climate change.

Like the rest of the country, areas of Alaska that have mobile coverage provided by mobile network operators (MNOs) that have opted in to IPAWS receive alerts and warnings directly from NWS or the state. Some communities in Alaska also use third-party subscription-based services to notify residents via text, phone call or e-mail.

30 On-road communities are those accessible via the road system while off-road communities are not accessible via the road system.
31 Harball, E. (28 November 2018). "Climate change will cost Alaska hundreds of millions a year, report finds". Alaska Public Media.
32 Betcher, S. (2021). Ice Edge – The Ikaagvk Sikukun Story. Farthest North Films.

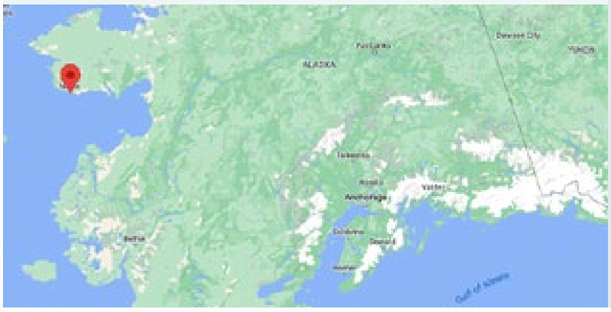
Sample communities

Two sample communities in Alaska were studied to provide local context. The communities were chosen for their high numbers of Indigenous peoples, social vulnerability and increased weather risk due to climate change. Insights from consultations with these communities are discussed further in section 4.

Nome, Alaska

Population size: ~3,699

Location: Off-road community unconnected to any other town by road and accessible only by air or water. Nome sits along the coast on top of continuous permafrost.



Recent disasters:

2009: flooding from storm

2011: storm surge and blizzard[33]

2012: coastal storm

Hazard mitigation plan:

Has both a hazard mitigation plan[34] and the Nome Tribal Climate Adaptation Plan.[35] Does not have a registered alerting authority so relies on the state alert system.

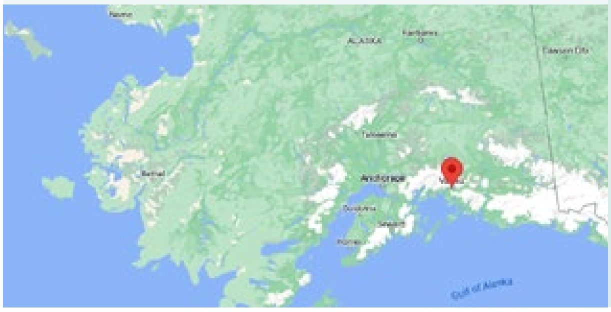
Socio-economic variables:

58% of the population is Native American, 27.8% are non-English speaking and 32.78% over the age of 25 have a high-school education.

Valdez, Alaska

Population size: ~3,985

Location: On-road community



Recent disasters:

2020: Valdez Glacier calving and separation

2020: Barry Arm landslide

Hazard mitigation plan:
Has an emergency and disaster management division and a plan in place.

Socio-economic variables: 21.67% of residents over 25 have a high-school education and 14% of families live below the poverty line (this is above the national average of 11%).

33 FEMA. (11 February 2021). "Flood mitigation in Nome, Alaska".
34 City of Nome, Alaska. (1 February 2017). Hazard Mitigation Plan Update.
35 Kettle, N., Martin, J. and Sloan, M. (2017). Nome Tribal Climate Adaptation Plan. Nome Eskimo Community and The Alaska Center for Climate Assessment and Policy.

3.2
Southeast

The Southeast includes vast expanses of coastal and inland low-lying areas that are highly susceptible to increased flooding, hurricanes, storms, changing rainfall and extreme heat, among other risks. The region has already seen an increase in storm surge. Between 2012 and 2021, there were at least 60 incidences of tropical cyclones, storms and related events, most notably Hurricane Katrina, multiple hurricanes during 2017 and the 2021 tornado outbreak. The estimated cumulative cost of these disasters was approximately $150 billion. Each of the states in the Southeast region – Louisiana, Arkansas, Mississippi, Tennessee, Kentucky, Virginia, North Carolina, South Carolina, Georgia, Alabama and Florida – have different forms of government, social vulnerabilities to disasters and EWS capabilities.

The fourth NCA report by USGCRP identifies the following climate risks in the region:

- Sea-level rise causing the erosion of coastal land and storm surges from tropical storms is estimated to cost $60 billion a year by 2050.
- Extreme downpours that lead to flooding of rural and metropolitan areas will impact transportation infrastructure, such as rail systems, roads and bridges, as well as drinking water and wastewater infrastructure.
- Higher temperatures leading to long summers and heat waves will have serious health and agricultural impacts.
- Warming oceans will lead to ocean acidification, threaten marine ecosystems and intensify storms and hurricanes.

Marginalised groups disproportionately affected by climate hazards

The Southeast is home to the most racially diverse population in the country, with some of the highest populations of individuals born outside the US and several native and foreign languages spoken. Although there are wealthy settlements, overall, the region is poorer than the rest of the country in terms of average household income, which is estimated at $42,830 per year; lower than the national average of $53,655.[36]

The Southeast is the least-educated region of the US, with several states ranking in the bottom ten.[37] Understanding the demographic and socio-economic composition of racial and ethnic groups in the region is important because these characteristics are associated with several other factors that may also influence the extent to which people are impacted by climate-related threats. This has real-world impacts on the region. For example, (1) low-income populations are less likely to be able to recover from disasters as they are most likely to be uninsured and it is unlikely that state or local government agencies can protect their assets; (2) there is a historical distrust of authorities, undermining EWS and exacerbating the negative impacts of disasters; and (3) the Southeast region has some of the highest levels of climate denial on an absolute basis.[38]

According to the EPA, minorities in the Southeast are 62 per cent more likely than non-minorities to live in areas most-projected to experience high-tide flooding. Also, those with no high-school diploma are currently 18 per cent more likely than those with a high-school diploma to live in areas most-projected to experience periodic inundation.

Existing EWS mechanisms for major hazards and risks

As in Alaska, most communities in the Southeast have hazard mitigation plans that include detailed hazard and vulnerability analysis. The development of these plans is generally supported by the states, and it is common for communities that share common characteristics to create these plans together. Many communities in the Southeast also use third-party subscription-based services to notify residents of hazards via text, phone call or e-mail.

Sample communities

The four communities selected in the Southeast represent both high-income and low-income communities, communities that have historically experienced high numbers of deaths due to disasters, communities facing specific increased threats from climate change and communities that have recently experienced large-scale disasters. Further discussion on the specific gaps in EWS in these communities can be found in section 4.

36 Allied Movers. (n.d.). "Regional Guide: The Southeast Cost of Living Breakdown".

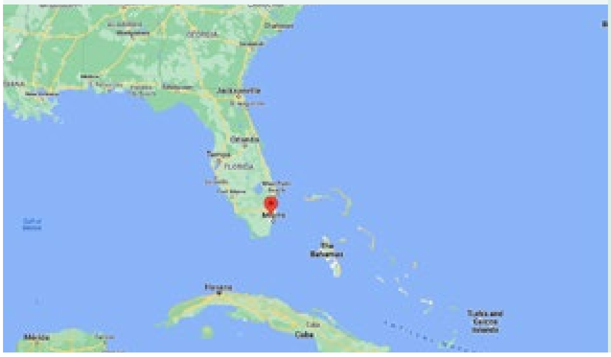
37 Louisiana ranks 48, Arkansas ranks 47, Alabama ranks 46, Georgia ranks 33, Florida ranks 22, South Carolina ranks 40 and Tennessee ranks 41 for education. See: McCann, A. (14 February 2022). "Most & Least Educated States in America".

38 Rates vary based on the nature of the question asked and the exact location across the associated seven states. See: https://climatecommunication.yale.edu/visualizations-data/ycom-us/.

Miramar, Florida

Population size: ~134,721[39]

Location: Topography is flat, low-lying lands averaging only 6 feet above sea level.[40] Ranked 5th among US cities most vulnerable to coastal flooding (93,000 of residents live in a coastal floodplain).[41]



Recent disasters:[42]

2015: coastal flooding

2016: Hurricane Matthew

2016: EF0 tornado

2017: Hurricane Irma

2017: coastal flooding

2019: Hurricane Dorian

2020: coastal flooding

Hazard mitigation plan:

Does not participate in IPAWS. Has an alternative alerting system (Alert Miramar) that requires users to register to receive alerts.[43]

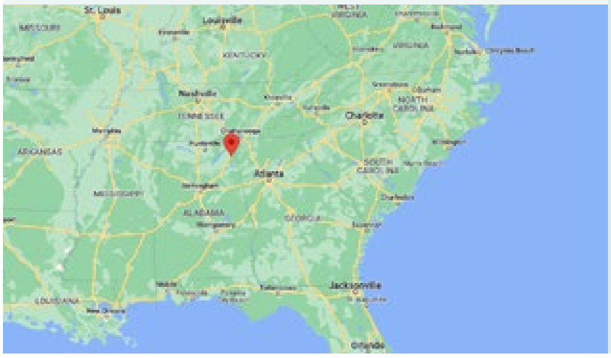
Socio-economic variables:

46% of the population born outside the US; 30% speak Spanish as their first language; 10% of residents live in poverty (lower than national average of 11.1%)

Dekalb County, Alabama

Population size: ~71,608[44]

Location: Mountains, sandstone plateaus, high bluffs and valleys. Mainly rural.



Recent disasters:

2004–2014: 30 tornadoes (compared to 10 tornadoes from 1990–2000)

2011: tornado outbreak

2017: Hurricane Irma

2019: severe storms, straight line winds, tornadoes and flooding

2020: Hurricane Sally

2022: winter weather (snow/ice)

Hazard mitigation plan:

Has an emergency management office. Authorised to issue alerts through IPAWS.

Socio-economic variables:

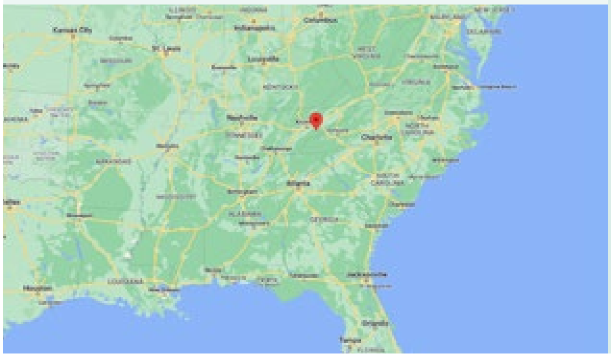
15% of residents live in poverty (compared to 11.1% national average);15.1% are of Latin heritage.

39 U.S. Census data for Miramar City, Florida: https://www.census.gov/quickfacts/miramarcityflorida
40 Broward County Emergency Management. (October 2012). Enhanced Local Mitigation Strategy (ELMS) for Broward County and its Municipalities and Private Sector Partners.
41 Climate Central. (25 October 2017). These U.S. Cities are Most Vulnerable to Major Coastal Flooding and Sea Level Rise.
42 Storm Events Database.
43 https://www.miramarfl.gov/283/Emergency-Management
44 U.S. Census data for Dekalb County, Alabama: https://www.census.gov/quickfacts/dekalbcountyalabama.

Sevier County, Tennessee

Population size: ~98,380

Location: Great Smoky Mountains, ridge-and-valley Appalachians



Recent disasters:

Increased temperatures causing drought and affecting crop yields

2016: Pigeon Forge Fire

2016: Gatlinburg Fires

2022: Pine Mountain Fire

Most recent wildfires destroyed 25,000 homes

Hazard mitigation plan:

Has a hazard mitigation plan in place. The county is registered with IPAWS and since the 2016 wildfires has used the additional features to send localised messages.

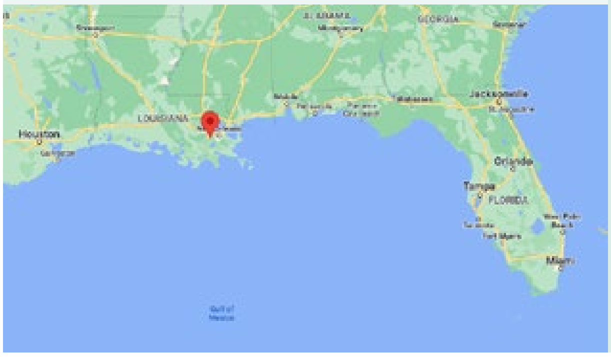
Socio-economic variables:

95% white and mostly educated; 13.8% of residents live in poverty (compared to 11.1% national average).

St. Charles Parish, Louisiana

Population size: ~52,549

Location: Swampy



Recent disasters:

Rising sea levels

2005: Hurricane Katrina

2020: Hurricane Laura

2021: Hurricane Ida

Hazard mitigation plan:

Participates in the national flood insurance program and is registered with IPAWS

Socio-economic variables:

26.5% are African American. Poverty rate reflects the national average; community has not completely rebuilt after Hurricane Katrina.

04

Gaps in EWS and opportunities for mobile and digital solutions in US

The research identified several gaps in EWS in the two US regions, primarily in monitoring and warning services and dissemination and communication. Many of the gaps are cross-cutting and reflect issues with how the federally developed alert and warning system is administered and the limited ability of local authorities to properly manage or access these systems. IPAWS is an advanced and complex system, and not designed to deliver personalised messages or provide hyperlocalised alerts affecting small populations, nor is it linked directly to well-known local response plans. The result is that residents tend to disregard warnings, and it is common for people to opt out of alerts completely and not participate in local risk planning.

Figure 6
Summary of EWS gaps

EWS component	Overview	Community feedback
Risk knowledge	Largely sufficient. Future efforts in this area can focus on hyperlocal data collection and analysis, which is already occurring in many places across the country. There is also scope for training local jurisdictions to meaningfully analyse data gathered from public sources like NOAA.	• **6 communities** indicated interest in having access to simple tools they can use to collect and understand relevant data on local risks.
Monitoring and warning services	Like risk knowledge, hyperlocal solutions will better serve remote and rural communities, especially Indigenous peoples and marginalised communities.	• **6 communities** referenced issues with inaccurate warnings. These involved issuing false alerts and misleading messages, which have led to confusion and lack of trust in the system. • **6 communities** expressed interest in using tools like cheap sensors to monitor items of interest in their communities (e.g. water temperature sensors in Alaska).
Dissemination and communication	The most significant gaps in EWS appear to be with communication, primarily infrastructure and devices. In general, this area offers the best opportunity to expand reach and customise EWS alerts to communities, specifically to marginalised groups.	• **3 communities** expressed concern about the number of people who have opted out of IPAWS and wireless emergency alert (WEA) messages. • **5 communities** referenced comprehension issues, including reading comprehension, language barriers, purpose of the message or confusion when outdoor warnings have multiple siren sounds/uses. • **3 communities** referenced messages not reaching everyone, including people with disabilities, tourists, phones purchased outside the US and those in remote areas. • **5 communities** referenced technology creating issues with dissemination, including outdated phones, message overshoot, lack of mobile coverage and issues receiving the messages between different carriers.
Response capability	Local leaders expressed concerns about the ability of the public to react properly despite having precautionary response plans in place.	• **3 communities** referenced an inability to respond due to physical ability, lack of awareness of response plans, non-residents (e.g. seasonal workers) being unprepared to respond, lack of trust in the government or perceived lack of risk. • **3 communities** cited systems testing, or lack thereof, as a contributing factor in the community's ability to respond. Gaps in the ability to operationalise plans, and limited participation in planning affect a community's ability to respond.

45 Source: Feedback from local organisations and civil society groups consulted.

The major gaps identified in EWS are discussed in more detail in the following section.

Technology issues

Issues with technology range from message overreach, lack of mobile coverage, use of old phones and differences in how large and small MNOs deliver messages.

For an IPAWS alert to be received in a community, local MNOs must have opted in to receive and transmit those alerts. While large MNOs have all opted to participate voluntarily, smaller providers, which typically serve remote or rural areas, often have not, primarily due to costs. This has left gaps in coverage in certain parts of the country, primarily in rural or sparsely populated areas. The primary reason cited for not opting in was the cost of upgrading equipment to be compatible with IPAWS.[46] These MNOs are typically very small with a small subscriber base, and often do not have roaming agreements with larger MNOs, which would generate extra income. They simply do not have the funds to upgrade.

In addition, several interview respondents noted a hesitancy to generate IPAWS messages, due to previous experience with having messages spread beyond their intended alert area into unaffected areas. This "message spread" is primarily due to the prevalence of older mobile devices that include wireless emergency alert (WEA) 1.0/2.0 technology, as opposed to WEA 3.0 devices. WEA 1.0 and 2.0 devices cannot differentiate precise alert locations, causing alerts to be issued to a broader audience than intended by the message originator. When a message is inputted to IPAWS for delivery via WEA, geographic coordinates are included that specify exactly where the message should be delivered. WEA 1.0/2.0 devices send an alert for every WEA message broadcast by a cell tower within range. WEA 3.0 devices are more advanced as they choose an incoming WEA message to determine whether the device is located within the designated coordinates and ignore or generate an alert accordingly.

All registered authorities we consulted that use IPAWS noted a lack of location accuracy (broader reach than intended), which can confuse the public and put more strain on local emergency services as people call to confirm whether the message applies to them.

While much of the US has robust mobile infrastructure, there are large areas that have minimal or no coverage. The lack of mobile service coverage has been addressed in numerous research, with most calling for the activation of FM radio chips in all mobile devices so that local FM radio broadcasts can still be picked up on the device even when there is no cell coverage.[47,48] MNOs would need to opt for this feature to be turned on in coordination with chip manufacturers.

How to close the gap

Given that IPAWS relies on disseminating messages via WEA and requires up-to-date devices to function, low-tech solutions (e.g. standalone SMS) can help expand access to populations lacking access to smartphones, for instance, or where mobile infrastructure is not suitable for IPAWS. In addition, working with community partners (such as a library or place of worship) may allow EWS alerts to reach farther and provide better access to local residents.

46 From interview.
47 Wireless Inclusive RERC. (2 February 2018). FM Radio and RBDS-Based Emergency Alerting, Volume 2018.
48 Pizzi, S. and Christel, S. (2015). FM Radio in Smartphones: A Look Under the Hood. National Association of Broadcasters.

Language barriers

Research clearly shows that messages transmitted in the primary language of the intended recipient are more effective.[49] Not understanding an alert could cause an individual to respond incorrectly or not at all. While the common alerting protocol (CAP) that accompanies IPAWS can issue alerts in multiple languages, the message sender must be able to produce them accurately. This applies to third-party messaging systems. Some third-party vendors that provide opt-in systems can automatically translate messages to the subscriber's preferred language, but communities need to purchase and maintain these systems and generate subscriptions from community members. As mentioned, while IPAWS can transmit in multiple languages, the WEA system can only transmit in English and Spanish.[50]

How to close the gap

Affordable solutions capable of sending alerts in multiple local languages and that can be managed locally are a necessity, and would complement existing systems at the community level.

High costs and human capital

The ability to generate timely, digital, localised warnings to the public is a significant challenge in some communities because of the cost, complexity and availability of local human resources to support the effort. Although IPAWS offers many features, the technology itself is quite cumbersome and designed to be managed by a team, not a community volunteer, which makes it less useful in small or rural communities. Local jurisdictions can choose to become an IPAWS message initiator, but the process is complex and requires monthly testing of the system. Writing and entering messages into the IPAWS system is very complex. The messages themselves are character-constrained and it can be challenging to get the intended message and actions across to the public using a limited number of characters, particularly for someone who rarely issues a message.

For some communities, which may only have part-time or volunteer public safety employees, the human hours and cost required for testing and training may not be justifiable given the infrequent need to use the system. Of the communities interviewed for this study, only two had ever issued their own IPAWS messages. Although it is possible for a state to issue a message on behalf of a local jurisdiction, that process can be time-consuming and may get interrupted for a variety of reasons,[51] including loss of communication of the person trying to generate the message. Interviewees also noted the ease with which people could opt out of IPAWS, which reflects the larger challenge of residents opting out of messaging they consider irrelevant.

49 Woody, C. and Ellison, R. (2014). Maximizing Trust in the Wireless Emergency Alerts (WEA) Service. CERT Division, Software Solutions Division, Carnegie Mellon University.
50 Federal Communications Commission (FCC). "Multilingual Alerting for the Emergency Alert System and Wireless Emergency Alerts".
51 Noted by two interviewees.

Underscoring these points, in 2020 the National Academies of Science, Engineering, and Medicine (NASEM)[52] identified five challenges to alerting systems in the US. The first was the slow adaptation of alerting systems due to high equipment and training costs that discourage jurisdictions from adopting new alert systems.

How to close the gap

Free or low-cost (licensing, training needs or technical maintenance skills) and open-source community platforms can enable community-based organisations to easily issue alerts to groups of individuals. Where such platforms are user friendly, they can also be operated on a volunteer basis.

Limited reach of warnings due to opt-in or opt-out features

Opt-in services offer an alternative to providing warnings; however, they are complicated and tend to be expensive.[53] All interviewees who had such a service noted that it was hard to convince people to sign up. Local authorities are also wary of overusing alerts since that might prompt people to unsubscribe. Smaller communities noted that group SMS lists were helpful, but those are unable to reach as many people that need to be alerted.

In terms of data access from mobile devices, local governments rarely, if ever, have access to data that might be associated with the EWS messages they broadcast. The message pathways are one-way from the message initiator to the message receiver. The exception is when organisations use an opt-in system that provides delivery information or create their own data collection methods. This might take the form of asking the public to provide them with feedback directly or to use an app designed specifically for that purpose.[54] Additionally, many local governments lack the funds to purchase data that might be available from mobile providers and may not have much use for it .

How to close the gap

Mobile solutions that allow two-way communication between message recipients and senders can incentivise residents to opt in to receive warnings. Also, there is a need for locally managed solutions that can restrict opt-out features for impending disasters categorised as high-level risks (subject to statutory guidelines).

52 Cybersecurity and Infrastructure Security Agency (CISA). (April 2020). Essentials of Alerts, Warnings, & Notifications.
53 Vendors will not share prices publicly, but the lowest price found in speaking with subscribers was several thousand dollars.
54 Yong, C. et al. (August 2019). "Understanding online civic engagement: a multi-neighbourhood study of SeeClickFix". Proceedings of the 2019 IEEE/ACM International Conference on Advances in Social Networks Analysis and Mining (pp. 1048–1055).

Delays in issuing warnings and conflicting messaging

The stakeholders we consulted noted that there is often a time delay with data from monitoring systems reaching local communities. This delay leads to inaccurate or inadequate warning dissemination. Two specific examples were noted. First, satellite imaging systems are able to automatically identify wildfires, but there is no way for that information to be sent directly to affected communities. It is first sent to the owner of the satellite system, which must then convey it via other mechanisms to the jurisdictions that have authority over response. This notice sometimes never happens. Delays in data transmission of river monitors can also lead to inaccurate responses. For example, if a particular stream or river gauge is only sampled for data every 30 minutes, it may fail to provide any warning of a flash flood.

One community pointed to an example where conflicting messages were given to the public because the various message originators were not coordinated. It was also noted that MNOs deliver messages at different times, which means that people in the same location could receive messages at different times.

How to close the gap

Ensuring that local communities have access to alerting tools to communicate directly with affected populations can reduce delays in warning at-risk populations. Synchronising the messaging delivered via various channels can address issues related to conflicting messages.

Cultural issues

The US also faces significant cultural challenges related to warnings about climatic and other risks. In general, it appears there is some public indifference about climate risks. As a recent Yale Climate Opinion survey notes, less than half of Americans (47 per cent) believe that climate change will impact them personally.[55] There is also a preference for personalised messaging, which leads to people ignoring or opting out of government mass messaging. There is a growing body of research that suggests Americans will opt out of mobile notification systems if they find them irritating or irrelevant to their lives, do not trust them, do not understand the messages or other related reasons.[56,57,58] However, social media platforms like Facebook that enable individuals to declare they are safe during a crisis appear to be more popular. Accordingly, a multi-pronged effort to address systems issues and cultural issues is critical.

How to close the gap

A majority of IPAWS notifications are sent by federal or state alerting authorities. As a result, these alerts lack local context and information. There is scope to apply user-centric design to ensure EWS alerts and messages resonate more strongly with users.

55 Yale Program on Climate Change Communication. (23 February 2022). "Yale Climate Opinion Maps 2021".
56 Bean, H. et al. (2016). "Disaster warnings in your pocket: How audiences interpret mobile alerts for an unfamiliar hazard". Journal of Contingencies and Crisis Management, 24(3), pp. 136–147.
57 Bean, H. (2019). Mobile Technology and the Transformation of Public Alert and Warning. Praeger Security International.
58 Bennett, D.M. (2015). Gaps in wireless emergency alert (WEA) effectiveness.

05

Addressing EWS challenges: lessons from LMICs

5.1 Why LMICs?

LMICs are at the forefront of the development of new technologies and new uses for existing technologies. This is due to the often limited regulatory frameworks in place;[59] the freedom to create new solutions rather than replace existing solutions; the "youth bulge", which contributes to higher social acceptance of new technologies and related applications; and a focus on local solutions to common problems.[60] The latter is significant, as it creates an environment where local innovators can apply different technologies to create low-cost solutions for their specific problems and context, whereas many commercially driven solutions are out of reach in low-resource environments.

This is characteristic of many innovations in LMICs that use low-cost technologies and can therefore be used more widely in different contexts. Moreover, being more easily transferable to low-resource environments may increase the ability to serve marginalised populations, especially in rural areas. This is the essence of frugal innovation and is relevant to EWS in the US given the opportunities to improve the climate resilience of underserved communities.

There are many examples of innovative, user-centred EWS design in LMICs. Although there are differences between LMICs and UMICs that can make the transfer of EWS innovations or practices unfeasible, lessons can be drawn from LMICs in terms of how a technology is co-designed (rather than the technology itself). When communities see that a service or tool is being modified to meet their needs, it becomes more relevant and makes them more likely to trust and promote the service. It creates an opportunity to support participatory planning and involve local leadership.

In the US, many of the top-down EWS tools have contributed to the "opt-out" phenomena. Introducing community-based solutions may enhance federal systems. For example, in Alaska, the services provided by NOAA and NWS are critical for alerting communities to the increased risk of flooding caused by climate change. However, in the research, small communities identified localised water temperature sensors as a resource of interest that is not provided by NOAA or NWS, although NOAA does provide related data for most communities.[61]

These examples highlight three components of LMIC innovations that are crucial for acceptance in UMICs like the US: (1) frugal innovation; (2) transferability or scalability; and (3) sustainable business models. Likewise, there are contextual success factors for UMICs. In adopting these innovations, other criteria should be considered and questions asked, including: (1) are such innovations allowable within local regulations and accessible given locally available resources? (2) does the solution fit the context? and (3) does it create an opportunity for private sector or other local intervention so that the solution can be adopted easily without excessive cost or community deliberation?

While reviewing relevant use cases from which to draw lessons, it is important to note that the examples are far from exhaustive. Also, innovative EWS solutions only address part of the problem. Context and existing power relationships determine access to, and use of, such innovations. It is therefore difficult to find a purely technical frugal innovation that, for instance, delivers effective digital EWS. Rather, innovative solutions are more likely to be part of a multi-channel EWS (in which digital tools are just one aspect) that have been designed with users and deliver information from trusted sources.

59 This lack of regulation can have negative effects. It is important to ensure experimental uses of technology have safeguards and risk assessments in place.
60 Baker, A. (31 May 2018). "The American Drones Saving Lives in Rwanda". Time.
61 NOAA National Centers for Environmental Information. (21 June 2022). "Water Temperature Table of the Alaska Coast".

5.2 Examples of EWS solutions in LMICs

1

Challenge:

Unresponsiveness to mass messaging due to message overreach or lack of trust results in warning messages being ignored, users opting out or non-users refusing to opt in.

Required action:

- Personalisation of messages
- Multi-channel messaging that helps users validate messages
- Co-design with communities

LMIC-inspired solution

Communities in Haiti Access New Technologies for Early Warning/ Response (CHANTER) – Mercy Corps initiative

Country: Haiti
Hazard type: Sudden-onset disasters
EWS component: Preparedness and response, dissemination of warnings
Technology used: SMS and interactive voice response (IVR) technology

Description
The solution supports communities by limiting loss of income, better protecting households and reducing the risks of physical harm from more frequent sudden-onset disasters in Haiti. Leveraging SMS and IVR technology through Viamo Inc's mobile communication platform via Digicel's Haitian mobile network, the CHANTER platform delivers training and information on extreme weather preparedness and first response practices, as well as early warning messages. The messages are tailored based on the recipient's livelihood activity and their location to ensure they receive useful information. Delivery is supported by a network of community-based organisations.

One of the benefits of this solution is positive behavioural change among users because of the relevance of the messaging received. Users also prefer that the messaging is interactive. This solution has been replicated in three other countries in the Americas.

LMIC-inspired solution

Disaster and Emergency Warning Network (DEWN)

Country: Sri Lanka

Hazard category: Flooding, extreme winds or storms, droughts, lightning, landslides

EWS component: Dissemination of warnings

Technology used: Mobile technology – cell broadcasting, location-based technology, SMS and software features of handset operating systems

Initiative: Disaster Management Centre, Sri Lanka and Dialog Telekom

Description

The DEWN systems use widely available mobile communications technologies, such as SMS, for early warning and cell broadcast to provide a cost-effective and reliable mass alert system. The network connects mobile subscribers, emergency responders, community leaders and the public to a national emergency monitoring centre housed at the national Disaster Management Centre (DMC). The principal objective of DEWN is to provide early warning of impending disasters to communities in disaster-prone areas using GSM networks. Some of the initial design requirements for the alerting system included immunity to mobile network congestion, availability of the service in local dialects, capability of mass dissemination, focused directions to specific locations or people and affordability for all communities.

To help improve the dissemination of alerts to communities not well covered by a telecoms network or where mobile phone penetration is low, Dialog developed the DEWN device, which is equipped with GSM functionality and an FM radio receiver. The device has a battery back-up, provides multilingual support and has a message acknowledgement function.

For certain categories of high-risk events, those within the affected area(s) cannot opt out of receiving warnings and information.

LMIC-inspired solution

AtmaGo

Country: Indonesia

Hazard category: Multi-hazard, including flooding

EWS component: Communication, response

Technology used: Web and Android-based social networking app

Description

A social networking app that provides relevant hazard information based on user-generated information shared through a city/town/neighbourhood user group. The app is designed to run with lower bandwidth than Facebook or WhatsApp. Members of each AtmaGo user group can create and share useful information on how to prepare for impending climate-related events. Other users in the same group can rate the posts for accuracy and usefulness. User-generated content is based on shared challenges and plans during a crisis and is therefore a very helpful tool in building community trust in messaging.

LMIC-inspired solution

National Cyclone Risk Mitigation Project (NCRMP)

Country: India

Hazard category: Cyclones

EWS component: All

Technology used: Community co-design

Description

The NCRMP is a multi-channel EWS strategy for coastal communities in India coordinated by the National Disaster Management Authority (NDMA). It was used successfully during Cyclone Fani in 2019 to evacuate 1.55 million coastal residents. A major lesson is engaging with communities in infrastructure management from the outset to ensure they have a sense of ownership and prepared to address vulnerabilities. The NCRMP involved local communities from the start by establishing village-level emergency task forces and mock drills in communities on actions to take in the event of a cyclone (e.g. trial runs of how to take shelter).

LMIC-inspired solution

DARAJA

Country: Kenya, Tanzania, Jamaica

Hazard category: Multi-hazard

EWS component: Monitoring and warning

Technology used: Community co-design

Description

DARAJA is a weather and climate information service platform that provides information on early warnings of extreme weather for vulnerable urban users, particularly those living in informal settlements. It does this by providing a platform that serves as an operational partnership between key actors involved and affected by weather forecasts and extreme weather alerts. Through a feedback loop, products are co-designed by vulnerable urban residents, national weather agencies, civil protection and disaster management agencies, telecommunications companies and research institutes, among others.

2

Challenge:

Language barriers due to the inability to communicate hazard information in multiple languages.

Required action:

- Low cost technology solutions, including machine learning and open-source data, that support multiple languages.

LMIC-inspired solution

Ushahidi

Country: Multiple, including Kenya

Hazard category: Various

EWS component: Risk knowledge, monitoring and warning, dissemination and communication

Technology used: Machine learning, database, multi-platform messaging

Description

Ushahidi is an open-source collaborative mapping platform that was developed iteratively, with innovations and upgrades generated during intensive use in resourced-constrained, time-limited and dynamic crisis situations. As a crowdsourced mapping tool, it allows otherwise scattered information to be synthesised into concise situational maps created from social media and SMS contributed by the public. The solution has several locally implemented sites that solve some of the most pressing needs identified in the US context. The crowdsourcing model was applied to the Haiti earthquake in 2010, allowing community-based data collection and messaging. In the 13 years since it launched, the platform has been deployed more than 200,000 times in more than 160 countries and more than 40 languages. In Kenya, it has been used to track and confirm verified information to curb the spread of fake news during a crisis. It is useful for rapid collection, analysis and management of crowdsourced data, and is an example of community validation of messaging.

3

Challenge:

Municipalities lack the technical or financial capacity to sign up as IPAWS message initiators.

Required action:

- Cheap digital alerting tools that do not require much training or maintenance

LMIC-inspired solution

Description

Solutions described above, such as Atmago, provide examples of low-cost and easy to use alerting options for messaging. There are countries (like India, through the NCRMP) that provide support funding to communities with vulnerable populations. In the US context, legislation allows a one-off grant rather than on-going support (required for training and monthly testing).

4

Challenge:

Residents are interested in getting more local information on climate risks at the community level.

Required action:

- Simple data collection tools for local use

LMIC-inspired solution

Moji

Country: China

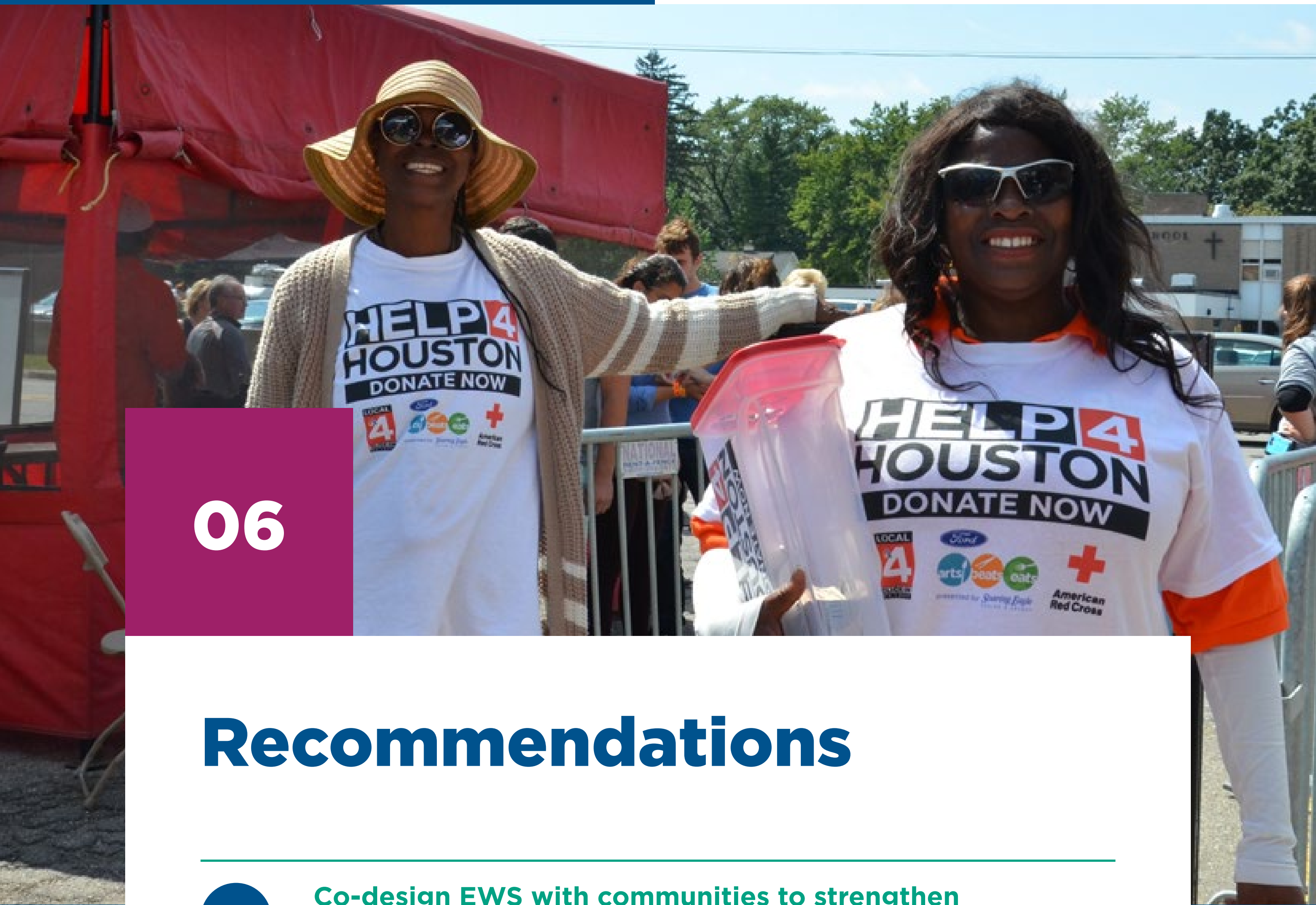
Hazard category: Various

EWS component: Risk knowledge, dissemination and communication

Technology used: Crowd-sourced data, machine learning

Description

Moji is a mobile app for monitoring the weather in real time and has been downloaded more than 500 million times. It leverages machine learning based on atmospheric pressure and data from depersonalised smartphones, which improves local area predictions. The smartphone sensors monitor atmospheric parameters and convert them into electrical signals that can then be collected by different mobile weather apps such as Moji. Many users are needed in a particular area to provide sufficient information, making this feature potentially useful in more densely populated areas.



06

Recommendations

1

Co-design EWS with communities to strengthen communication, dissemination and response capability.

The current approach in the US aims to do this, but is often poorly implemented. Bringing American community organisations and municipalities together to develop new and/or modified EWS delivery models for IPAWS message initiation, or transfer to another system, will help develop localised models and strengthen community trust. In the regions we studied, there are examples of community organisations that are likely to have greater capacity to sustain the support for IPAWS training and testing required for message initiation than municipalities alone (e.g. Alaska Native Corporations, health care systems or community centres). Appointing a group from the Alaska Native Corporations to receive messages from IPAWS and transition them to a local dissemination solution like Ushahidi would provide a low-cost solution to expand communications. These localised solutions can also adopt a wide variety of message delivery options.

2 Investigate opportunities to leverage multi-channel EWS communication to reach a wider group of users and improve users' responses to messages.

In the US, message recipients are more likely to act if they receive a warning multiple times from different platforms. Message solutions like CHANTER could be used in combination with existing systems to amplify messages and make them more relevant, resulting in more specific messages being delivered to recipients' phones. When local communities are stakeholders and involved in managing such solutions, messages sent through the community-based channel would most likely be considered trustworthy and, therefore, prioritised.

3 Strengthen multi-language EWS messaging.

Leverage low-cost systems to rebroadcast messages in multiple languages. Local governments may also use other systems to auto-translate messaging for minority languages in coordination with user representatives from these communities. There is also an opportunity to pilot AI-powered auto-translate systems, for example, talking books to reach users who are not literate. In the US, there is an opportunity for federal or state governments to explore funding mechanisms that would support the local adoption of these kinds of innovations. For example, block grants, or federal funds earmarked for specific state or local programs, could be made available to complement existing EWS with online solutions such as Ushahidi. Such an approach would allow local innovation fit for communities and complement the largely federal infrastructure currently in place.

4 Engage partners in educating customers about WEA and local opt-in alert and warning systems.

Local communities can partner with local wireless operators to provide information to consumers on the benefits of WEA and local opt-in systems. This could be implemented as a corporate social responsibility initiative, alongside civil society groups and county emergency offices, hosting targeted workshops and advocacy campaigns that highlight the importance of residents signing up for warning messages and gathering feedback from residents on their preferences and potential challenges related to receiving disaster warnings.

Annexes

Annex 1: Stakeholder mapping

The stakeholders and focus group participants engaged as part of this research include the following:

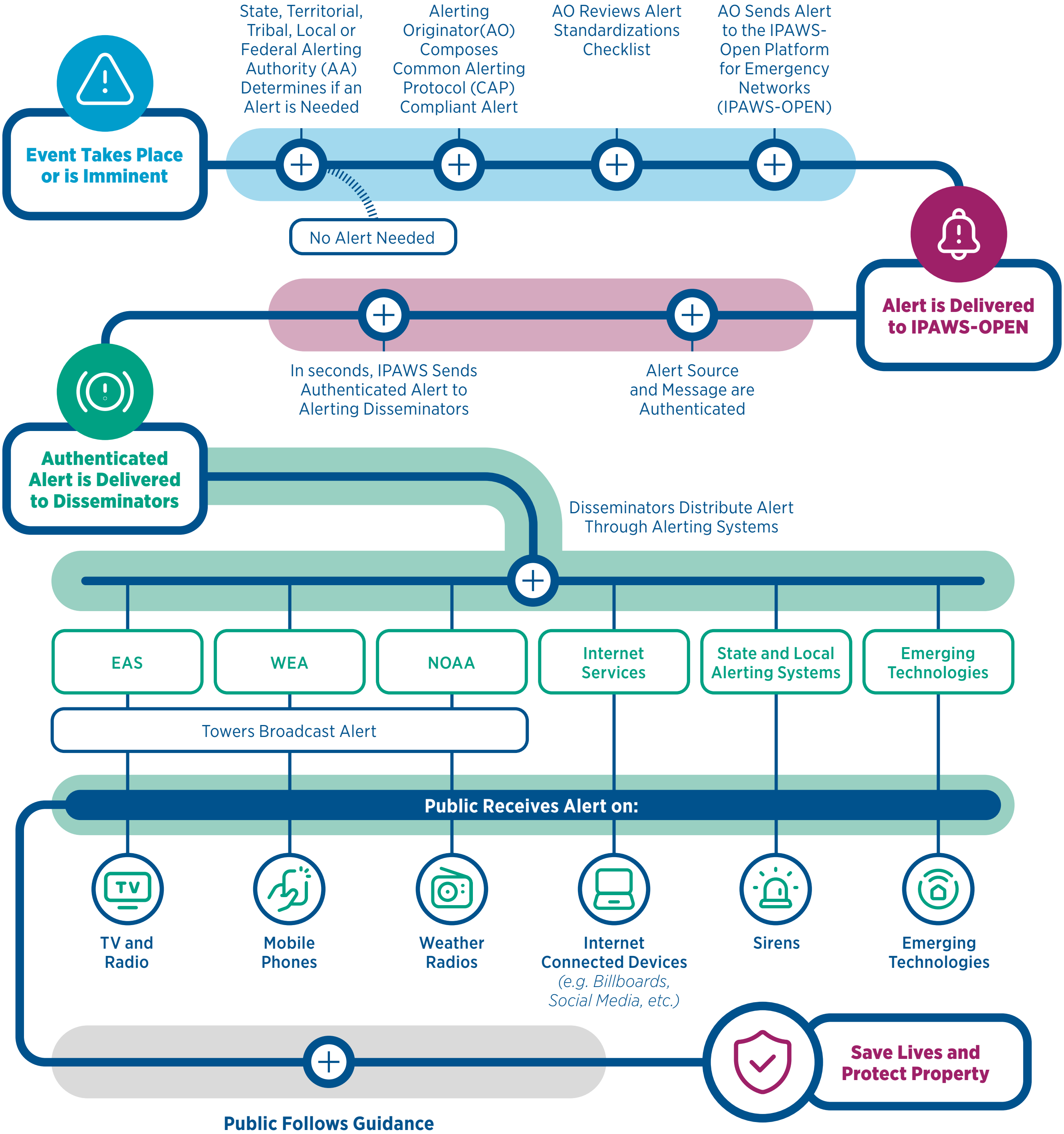
Stakeholder category	Organisation
Federal or state government agencies	• National Weather Service (NWS) • Federal Emergency Management Agency (FEMA) Integrated Public Alert & Warning System (IPAWS) • Center for Arctic Security and Resilience (CASR), Alaska • State of Alaska Homeland Security and Emergency Management
Civil society/local organisations	• Nome Community Center, Alaska • Valdez Emergency Management, Alaska • Valdez Convention and Visitors Bureau, Alaska • Sevier County Emergency Management, Tennessee • DeKalb County, Alabama • City of Miramar, Florida • Center for Independent Living Broward, Florida • St. Charles Parish Assessor's Office, Louisiana • Nome Chamber of Commerce/Police/Ambulance, Alaska • University of Albany – College of Emergency Preparedness, Homeland Security and Cybersecurity • SweetSense Inc. • Global Human Development Program, Georgetown University • City of Riverside Office of Emergency Services (California) • City of Los Angeles Emergency Management Department (California) • Atlanta-Fulton County Emergency Management Agency (Georgia)
Private sector	• Everbridge • CodeRed/OnSolve
International organisations	• The Global Resilience Partnership • Mercy Corps • Resurgence • TechChange • Mott MacDonald

Annex 2: Alert distribution through IPAWS

The Integrated Public Alert and Warning System (IPAWS) quickly distributes alerts to the Public through multiple broadcast pathways including the Emergency Alert System (EAS), Wireless Emergency Alerts (WEA), National Oceanic and Atmospheric Administration (NOAA), internet services, state, local, tribal and territorial alerting systems, and emerging technologies as depicted below.

Responsibility Key

- Alerting Authority and Originator
- DHS -FEMA
- Alert Disseminators
- Public



gsma.com

For more information, please visit the GSMA website at www.gsma.com

GSMA HEAD OFFICE
Floor 2
The Walbrook Building
25 Walbrook
London EC4N 8AF
United Kingdom
Tel: +44 (0)20 7356 0600
Fax: +44 (0)20 7356 0601