Climate Change, Risk, and Resilience in WASH and Agriculture Projects

AUGUST 2021

CLIMATE CHANGE, INTEGRATED WATER RESOURCE MANAGEMENT, AND AGRICULTURE

Climate change means a change in average weather conditions (such as rainfall, temperature, or humidity) over years or decades. The earth's climate has always changed, but the changes in climate recorded in recent years are unusual and are mainly caused by human activity such as burning fossil fuels (Intergovernmental Panel on Climate Change [IPCC] 2021). Climate change can seriously harm the natural environment that humans are adapted to, and it can make growing crops and providing adequate water supplies more difficult. Climate change also makes natural disasters (such as storms, droughts, landslides, and floods)[1] more common and more dangerous. Warmer weather and changes in rainfall patterns can also increase the range and spread of insect-borne diseases such as malaria. Climate change therefore threatens development gains in the world's poorest countries, including advances in water, sanitation and hygiene (WASH) as well as agricultural practices and productivity.

1 See Appendix 1.

Major efforts are being made to limit the average rise in global temperature to 1.5°C (2.7°F), but it is far from certain that humans will be able to achieve this (IPCC 2018).[2] If the global temperature rises by more than about 1.5°C, the impacts are likely to be particularly severe, and these impacts will be worst for the world's poorest people (Steffen et al. 2018). Even small reductions in agricultural output in some countries, for example, could mean that many more people will not have enough food to eat. Climate change has already reduced the productivity of food crops and fisheries in parts of Africa, and these impacts are predicted to get worse in the future even under low emissions scenarios (see box 1). Climate change will also impact the volumes and quality of water resources, with serious implications for existing and planned WASH infrastructure. For these reasons, climate change is considered to be a global security risk, with implications for the national security of most countries (Toulmin 2009).

Water resources and climate are closely linked through precipitation, evaporation, and other physical processes (de Wit and Stankiewicz 2006; Hu, Teng, and Zhu 2019). Contemporary approaches to water management such as Integrated Water Resources Management (IWRM)[3] take these links into account. The IWRM approach encompasses a wide breadth of scales, sectors, and stakeholders. IWRM considers the various purposes, benefits, costs, and trade-offs of using water, including the environmental goods and services that water supports as well as the agricultural benefits of water for grazing and irrigation. It also recognizes water's social, cultural, and religious values. An important step in informing the design of any IWRM approach is to understand the impacts that climate change will have on the volume and quality of water resources in a given catchment. Better information on climate change impacts supports better planning, which reduces risk. As the effects of climate change on water resources become more obvious, it is clear we can no longer assume that past conditions will continue to prevail.[4] We should make use of available tools to understand how climate change will impact WASH and agriculture and the subsequent impacts these changes will have on the world's poorest people.

LEVERAGING CLIMATE INFORMATION TO IMPROVE DEVELOPMENT GAINS

Modern development programs emphasize the importance of enhancing resilience,[5] which includes improving our ability to adapt to climate change and to recover from climate-related shocks such as droughts and floods by understanding and quantifying climate-related risk.[6] Making use of climate information services (CIS) to improve climate change planning is a powerful way to boost resilience and reduce risk (Hallegatte 2012; United Nations Office for Disaster Risk Reduction [UNDRR] 2021). Also known as "hydrometeorological systems," CIS combine the scientific instruments for measuring weather and climate conditions with the human, financial, and institutional systems that operate and interpret them (see the section below, "What are CIS?"). CIS have enormously improved the understanding and knowledge of climate change impacts in higher income countries and they have tremendous potential to reduce risk and improve outcomes for many middle- and low-income countries (Hallegatte 2012).

2 Humans have already caused a 1°C average rise in global temperature compared to pre-industrial levels, and average global temperatures are increasing at about 0.2°C per decade (IPCC 2018; IPCC 2021).

3 For more information on IWRM, see PRO-WASH's IWRM learning note, available at: https://www.fsnnetwork.org/resource/integrated-water-resources-management-iwrm-what-it-and-what-does-it-mean-resilience-food

4 For example, one of the contributing factors to the "Day Zero" water supply crisis in Cape Town, South Africa in 2017/18 was that planners relied on past average rainfall conditions in their calculations. In fact, climate change means that severe droughts are growing more common in the Cape Town area.

5 Some development programs and initiatives have focused on mitigation (including lowering carbon emissions and decarbonization), but as the frequency and intensity of climate shocks increases, reversing development gains, there is an emphasis on the importance of adaptation and resilience to climate shocks (Chaffin, Gosnell, and Cosens 2014).

6 Climate risk assessment and risk mitigation is a core component of USAID-funded development programs, and as a result, USAID requires that climate risk management (CRM) be incorporated into development project planning, using a standardized approach.

CIS are important to water management and governance because they can help decision-makers predict the future quantity and quality of water resources as the climate changes, also providing information on related issues such as temperature and evaporation potential. This makes CIS important to both agricultural productivity and WASH outcomes. CIS are an essential part of IWRM because a stronger understanding of weather, temperature, water, and other climate-related metrics can support better planning and more equitable use of scarce resources. CIS are an essential input into IWRM planning because weather, temperature, and other climate-related metrics are fundamental to IWRM. At the same time, hydrological data such as river flows and stages, evaporation, soil moisture, and other parameters collected by hydrologists is in turn used for refining and calibrating CIS, illustrating the interdependency between climate and hydrology.[7]

The challenge in many middle- and low-income countries is to identify and leverage available CIS and to improve CIS to derive benefits for both economies and societies under pressure from climate change.

FIGURE 1. Halima Kahiya, Station Manager at Wajir Community Radio.

March 2018, Wajir, Kenya. Halima Kahiya, Station Manager at Wajir Community Radio. The station is a key, and popular, component of the BRACED program. It broadcasts current local weather information so pastoralists know to move their herds—key information unavailable from the national weather reports. It also airs programming for Wajir and parts of neighboring countries on gender and natural resource management. With Mercy Corps' help, the station has transitioned over to digital and has boosted its signal, more than doubling its audience from 120,000 people to 270,000 people. "It's upon the community to fund the radio station," says Halima Kahiya, the station manager. "But a community that is living below the poverty level, it is very difficult to sustain. So most of the staff here are volunteers, we are working for the community. We cannot kill the station, this is a very big investment and the community really appreciates it."

7 The US Government (USG) Global Water Strategy recognizes that CIS and water resource planning are closely linked (USG 2017).

WHAT ARE CLIMATE INFORMATION SERVICES (CIS)?

Before we discuss how to make better use of CIS, it is useful to understand these systems a little better. CIS include weather radars, satellites, water level meters, and other hardware that monitors **physical parameters** such as air and sea temperature, humidity, river flows, wind velocity, and barometric pressure. Just as important are the **social and institutional systems** and the people that support and link this hardware. No CIS can survive without funding, expertise, training, and collaboration. CIS also includes applied climate research and climate modeling that interprets the data and results and in turn feeds back into the CIS design so that the CIS becomes more accurate over time. Finally, there is no use in weather and climate data and modeling if these are not turned into **useful knowledge products** for decision-makers. CIS therefore also includes reports, risk assessments, forecasts, warnings, expert opinions, and tools.

CIS is not a single system or tool; it is a more complex arrangement of hardware and human resources that together offer improved and powerful weather and climate forecasts and risk assessments.

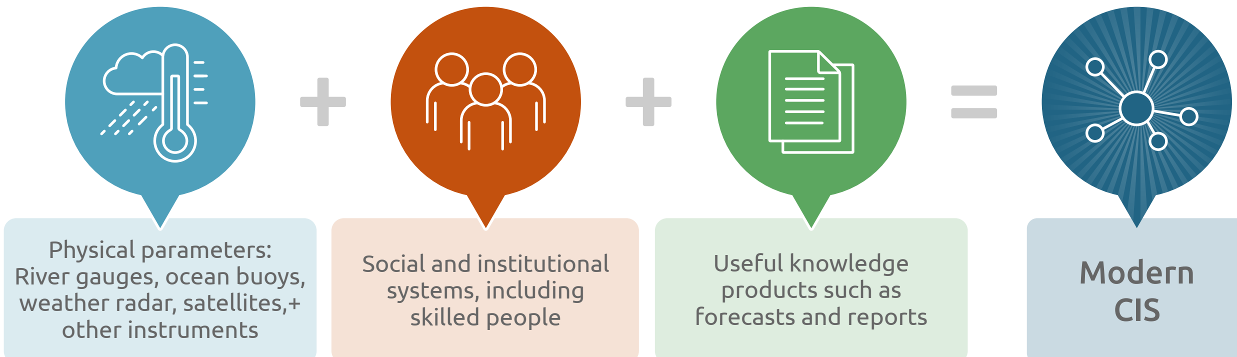

FIGURE 2. Modern CIS

As an example, by linking data on rainfall, river flows, soil and atmospheric moisture, groundwater levels, and wind speeds, and combining this information with crop prices and existing land use, CIS can help farmers prepare for future drought or rainfall conditions at detailed scales.[8] If a hurricane or other extreme weather event is forecast, a CIS can not only track it more accurately, but also help to predict its impact on river flows, sea levels, wind speeds, slope stability, and many other physical parameters (see appendix 2 on Cyclone Idai in southern Africa). These in turn affect infrastructure such as transport, power, communications, and water supply—vital to sectors like aviation, communications, tourism, security, healthcare, education, and many others.

Physical information from CIS can also be combined with socio-economic information such as agricultural production, health trends, human settlements, population trends, transport networks, tourist preferences, and many others. This combination can provide insights, projections, trends, vulnerability analyses and other knowledge products for decision-makers and development practitioners focused on certain regions or sectors. They can be generalized or highly specific. These information products, based on CIS, can in turn greatly boost development outcomes, support investment planning (particularly in agriculture), improve resilience to shocks and stresses, and help prepare for climate change.

8 A good example of this is the ongoing collaboration between the Intergovernmental Authority on Development (IGAD) Climate Predictions and Applications Centre (ICPAC) in East Africa and the EU's Joint Research Centre (JRC) to provide regular information on crop and rangeland conditions across East Africa every ten days. See https://www.icpac.net/.

In global regions such as North America, Europe and east Asia, the impact of CIS in sectors like agriculture, aviation, water infrastructure operation, power grid management, tourism, health planning, transport logistics, and disaster preparedness has added billions to economies and saved hundreds of lives (Lewis 2018). These benefits are being transferred to middle and low-income countries, where improved CIS can boost economic growth, jobs, and economic stability. As weather events become more extreme, potential costs and losses increase, and the argument for risk reduction through better use of CIS grows stronger.

It has been conservatively estimated that if CIS in low-income countries were similar to CIS in the USA, up to 23,000 lives per year could be saved, asset losses of up to US$3.5 billion per year could be avoided, and additional economic benefits of another US$30 billion could be realized (Hallegatte 2012). More generally, the World Meteorological Organization's (WMO) State of Climate Services report confirms that the benefits of strengthening hydrometeorological systems globally outweigh the costs by about 80 to 1 (WMO 2019).

The CIS revolution over the past two or three decades is due to incremental improvement across several areas, including increasing computing capacity and demand for more sophisticated information products to inform policy and decision-making.[9] It has been mainly a systems revolution—in other words, a revolution in the way that different datasets and disciplines have been combined and in the ways that the resulting vast and diverse datasets have been examined and processed. CIS rely ultimately on the people, finances, and institutional systems that support and manage them. Without these, the full benefits of CIS in supporting livelihoods, improving incomes, and strengthening resilience to climate shocks are not realized. Fortunately, much of the infrastructure hardware, such as satellites and weather radar, is already in place globally. This can lower the cost of improving CIS in middle- and low-income countries, where an important challenge is to boost funding, expertise, and training to leverage available CIS.

FIGURE 3. Indigenous *Schotia Afra* drought-resistant trees awaiting planting, Eastern Cape, South Africa

9 For example, in the last twenty years the CIS revolution has made weather and climate forecasts much more accurate. It is estimated that the average lead time of weather forecasts has been improving at least a day every decade, and today's five-day weather forecasts are as good as the two-day forecasts of twenty-five years ago (Dupar, Weingärtner, and Opitz-Stapleton 2021).

Box 1. The IPCC, Climate Risk, Gender, and Food Security

The United Nations has convened the IPCC as its body for assessing the science related to climate change. The IPCC is currently producing its sixth assessment report, due in February 2022. This report is expected to reiterate and emphasize the grave threat that anthropogenic climate change poses to global development gains, livelihoods, and ecosystems.

Climate change is already impacting Africa, with negative effects on food and water security, human health, ecosystems, human settlements, and economic growth (Niang et al. 2014; World Bank 2016). Furthermore, human and natural systems are thought to be adapting more slowly than the climate is changing, implying a growing risk (Steffen et al. 2018). For example, drought frequency and duration is highly likely to increase over northern Africa, the Sahel, and southern Africa. Better mitigation, adaptation, and resilience is urgently needed to reduce climate-related risks (IPCC 2018).

Women are often at the forefront of decision-making on matters of household nutrition, resilience, and preparedness; they are frequently primarily responsible for the consequences of climate-related shocks such as caring for the sick,[10] providing food, or ensuring basic services such as shelter and a daily water supply. Women also account for nearly eighty percent of the agricultural sector in Sub-Saharan Africa that is at particular risk due to a changing climate (Dethier and Effenberger 2012). For these reasons, gender disparities and climate change should be considered together.

The IPCC confirms that climate change impacts entire food systems across Africa, including production, processing, storage, distribution, and consumption (IPCC 2018). For example, warmer weather can mean more pests and more challenging food storage, and bigger storms and floods can threaten food transport infrastructure. It is therefore vital that the information that CIS can provide reaches all stakeholders, particularly systematically disadvantaged and vulnerable groups such as women and the rural poor.

Climate change, CIS, and resilience should inform both local grassroots resilience initiatives and high-level regional plans and strategies. The recent acceleration in the use of digital technology in response to the COVID-19 shock suggests that there may be new opportunities to reach people and support their decisions for their businesses and families with useful knowledge products and tools.

10 Tens of millions more people are expected to be exposed to malaria in parts of Africa, along with millions more expected to be exposed to dengue and Zika viruses, compounded by increases in diarrheal disease.

WHAT CAN RFSAS AND PARTNERS DO?

There are three primary ways in which RFSAs and partners can make better use of CIS and thereby improve climate resilience. These activities are consistent with the United States Agency for International Development's (USAID) focus on risk, resilience, and climate change and its requirement for CRM:

1. **Leverage existing CIS.** Every country in the world has CIS capacity or access to CIS data from international providers, although this capacity and access varies (see appendix 1). Using knowledge products derived from CIS can reduce project risk and increase resilience. It is sensible to devote resources to understanding the advantages offered by CIS at the local level. This includes working on ways to make the information from CIS available and accessible to all. For example, promising work on using radio broadcasts for weather forecasts and disaster warnings is already underway in parts of South Asia and East Africa, with the aim of bringing CIS knowledge products to the wider public to improve resilience (Dupar, Weingärtner, and Opitz-Stapleton 2021; Lambert 2019).

2. **Engage CIS providers regularly.** Development projects such as RFSAs can engage with local CIS providers such as national meteorological departments to better understand the products that they offer and to obtain information on weather and climate risks.[11] By working with CIS providers, clients such as RFSAs and partners help to create demand for CIS, shape the final knowledge products, and help ensure that these products are accessible and relevant to the communities that are served. For example, products could include more detailed local forecast information that impacts local crops and livestock, such as whether anticipated rainfall or temperature thresholds might be reached. Better and more accessible disaster warnings are also needed.

3. **Advocate for better CIS.** International non-governmental organizations (NGOs), donors, and other partners have considerable convening power, and RFSAs work closely with local and national governments. This puts NGOs and RFSAs in a powerful position to advocate for or lobby alongside partners working on these issues—such as the Global Framework for Climate Services, the World Bank, the WMO, and regional providers such as ICPAC—for better CIS capacity at the national and regional levels and to participate in capacity strengthening activities. For example, by ensuring that CIS is on the agenda of international antipoverty initiatives, projects have a better chance of benefiting from the latest forecasts of climate conditions and their impact on water resources and food security. Engagement with universities with expertise in CIS and related areas is also recommended.

CIS products could include more detailed local forecast information that impacts local crops and livestock, such as whether anticipated rainfall or temperature thresholds might be reached.

11 National meteorological and hydrological services capacity is often inadequate (USAID 2019). Where local CIS is weak or absent, regional and international providers can be approached.

CIS RESOURCES FOR RFSAS

Some examples of international and regional resources for CIS are shown below. Remember, it is also useful to first investigate the resources available from the national CIS provider in your country first for weather and climate services and knowledge products. See Appendix 1 for more information.

1. The **SERVIR** (https://www.servirglobal.net/) partnership between the United States' National Aeronautics and Space Administration (NASA) and USAID helps developing countries use satellite data to address critical challenges in food security, water resources, weather and climate, land use, and natural disasters. SERVIR has a large collection of services that use geospatial data to support resilient development.

2. **ICPAC** is a climate center providing CIS to eleven East African countries, aimed at boosting resilience in a region deeply affected by climate change and extreme weather. ICPAC coordinates regional responses to drought, and its water resources program works to enhance collaboration on water resources. ICPAC is an initiative of IGAD[12] that produces popular weekly forecasts at 10 x 10km resolution. These help stakeholders prepare for extreme weather and mitigate risks associated with floods, drought, or heavy rainfall. ICPAC also offers seasonal forecasts to help farmers and others prepare for the season ahead. Monthly forecasts also help refine the seasonal forecasts. All of these products are available from the ICPAC website at https://www.icpac.net/.

3. The **European Centre for Medium-Range Weather Forecasts** (ECMWF) is an independent intergovernmental organization supported by European member states, based in the United Kingdom (UK). ECMWF is both a research institute and a 24/7 operational service, producing and disseminating numerical weather predictions. These weather predictions are regional and global in focus and the ECMWF maintains an extensive archive of meteorological data. Their website is at https://www.ecmwf.int/.

4. The **WMO** coordinates Regional Climate Outlook Forums (RCOFs) that bring together national, regional, and international climate experts and produce regional climate outlooks. The forums also advocate for ways to improve the use of CIS products. Their products can be found at https://public.wmo.int/en/our-mandate/climate/regional-climate-outlook-products. The WMO also offers climate services for health fundamentals and case studies for improving public health decision-making in a new climate (https://public.wmo.int/en/resources/library/climate-services-health-case-studies).

5. The **Southern African Development Community (SADC) Climate Services Centre** is the regional climate center for the SADC region that coordinates the outputs of SADC national meteorological and hydrological services. The regular Southern Africa Regional Climate Outlook Forum (SARCOF) meetings produce seasonal outlooks and long-term rainfall information. Coordination also takes place with the African Centre for Meteorological Application for Development (ACMAD) and with Global Producing Centers (GPCs) such as the UK Met Office and Météo-France. Their website is at http://csc.sadc.int/en/.

6. **USAID's** climate risk screening and management tools are designed to improve the effectiveness and sustainability of development interventions, and can be found at https://www.climatelinks.org/resources/climate-risk-screening-and-management-tools.

12 IGAD, headquartered in Djibouti, is a trade and development bloc established in 1996 in the Horn of Africa region. It consists of eight member states with a combined population of about 240 million people.

CONCLUSIONS

Climate change is a global challenge, yet the effects are felt locally, often by the world's poorest people. Past conditions are no longer an adequate guide to the future, and business as usual is no longer an adequate strategy (Ripple et al. 2020). The growing global climate crisis threatens development progress. International NGOs, development projects, and national development agencies and departments are among the most important potential users of climate, weather, and hydrological information. By leveraging all of the resources at our disposal, including CIS, we can lessen the risk that climate change will severely impact livelihoods and undermine development outcomes.

CIS has had a large and positive impact on numerous sectors in global regions where these systems are integrated into operations and planning. There is a significant opportunity for other regions to benefit from these advances and for development programming to further reduce climate-related risk by integrating CIS into project plans and climate risk management strategies.

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APPENDIX 1
A Closer Look at CIS Providers: National and Regional Offices, GPCs, and the WMO

The WMO is the agency of the United Nations tasked with promoting cooperation in atmospheric science, climatology, hydrology, and geophysics. The WMO helps to coordinate the weather observations of its 193 member countries and territories, and it also provides standards on observations and reporting. Extensive global collaboration in CIS and related activities is important, because a vital component of CIS are the linkages between different disciplines and skills to transform climate information into knowledge products that are accessible and that support better decision-making.

Most countries have a national meteorological office that is responsible for daily weather forecasts and other routine weather, climate, and hydrological services in that country, and these offices should be the first stop in the search for CIS products. However, the considerable computing and human resources needed to develop global weather and climate predictions mean that only a few national offices or consortia have the capacity to develop operational weather prediction models or global climate models (GCMs). GCMs are essentially complex mathematical descriptions of the important physical and chemical processes governing climate, including the processes in the atmosphere, on land, and in the oceans.

For near-term weather forecasts, the United States operates the Global Forecast System (GFS), the UK Met Office has its Unified Model (UM),[13] and the French weather service Météo-France has ALADIN.[14] In Europe, the ECMWF has its Integrated Forecast System that produces global and regional weather forecasts. Each model has advantages and drawbacks, and some are better for certain parts of the world than for others. Models are constantly refined as new data becomes available.[15] Many outputs are available to collaborating national meteorological offices and can be used to enhance local forecasts, particularly where local modeling capacity is not yet established.

The European Union's earth observation program, known as Copernicus, is designed to improve earth observation across multiple fields, particularly in CIS. Copernicus combines satellite data (including the Sentinel satellite missions) with sea, air, and ground-based sensors to develop a high-resolution picture of the earth's environmental health. Much of the data and information is made available free of charge. As an example of the practical use for such information, data from the Sentinel satellite missions is the basis for the Mzansi Amanzi surface-water assessment methodology[16] in southern Africa.

13 The UK's UM produces forecasts across most of the SADC at a grid spacing of 4.4 km, including flash flood advance warning in some parts of the region (Bopape et al. 2021).

14 The ALADIN acronym stands for Aire Limitée Adaptation Dynamique Développement International.

15 For example, to understand how well forecasts have performed in the past ("forecast skill"), a data-intensive process called "hindcasting" can be used. Hindcasting compares past model predictions against what actually occurred. In some cases this can identify systematic "model bias" that can then be corrected. Model "skill maps" can be produced for the globe or for a single region, showing where forecasting is most accurate.

16 Mzansi Amanzi is an initiative that uses satellite data to prepare accurate monthly surface-water volume reports in the Republic of South Africa, with potential to expand into the southern Africa region. Their website is at https://www.water-southafrica.co.za/

Seasonal forecasts for some parts of the world are inherently more accurate than for others. For example, the tropics generally have “higher predictability.” In contrast, regions such as southern Africa are considered only “somewhat” predictable, making seasonal predictability more difficult.

The WMO designates some organizations and national meteorological offices that make global seasonal forecasts as Global Producing Centers of Long-Range Forecasts, sometimes shortened to GPCs. GPCs must meet certain reporting and data standards and meet a certain minimum level of forecasting skill.[17]

The WMO also presides over Regional Climate Centers, which are often hosted by national meteorological offices. The role of Regional Climate Centers is to build regional climate services and coordinate RCOFs, which coproduce consolidated regional climate forecasts for the region. For example, SARCOF produces seasonal forecasts and long-term rainfall data for the SADC region (see above). National climate outlook forums or NCOFs are also held, hosted by national meteorological offices.

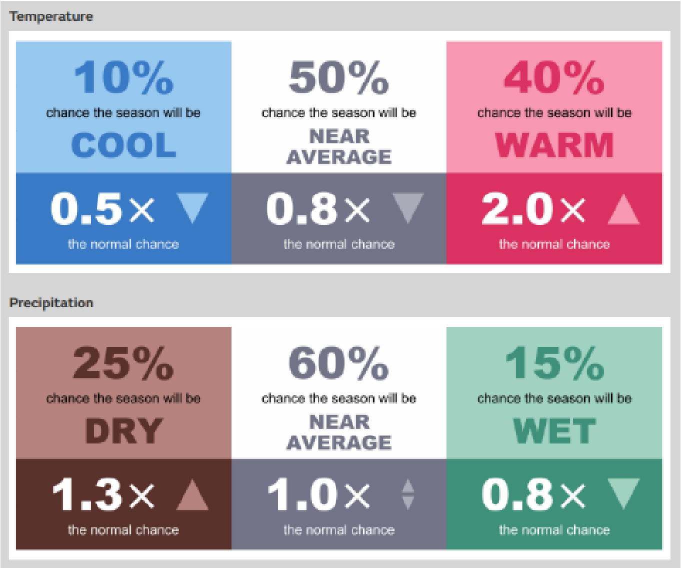

FIGURE 4. Example of a three-month outlook for temperature and precipitation in the UK, provided by the UK Met Office (www.metoffice.gov.uk).

17 There are currently thirteen WMO GPCs around the world. The model outputs of the GPCs are combined into a multimodel ensemble by the WMO Lead Centre of Long Range Forecast in Geneva, Switzerland.

Box 2. National Oceanic and Atmospheric Administration's GFS and Drought Early Warning

This box describes the national meteorological office of the United States and the role that it plays in the United States and globally in reducing climate uncertainty and boosting planning capacity. The United States' National Oceanic and Atmospheric Administration (NOAA) is in the process of upgrading its GCM, known as the GFS, to further improve weather forecasting capabilities in the United States. This upgrade will strengthen NOAA's hurricane forecasting, snowfall location predictions, and heavy rainfall forecasts. For the first time, the GFS will be linked with a global ocean wave model, ensuring better wave prediction and allowing current wave forecasts to be extended from ten days out to sixteen days.

Other elements of NOAA's earth observation systems are also improving. For example, the Constellation Observing System for Meteorology, Ionosphere, and Climate-2 (COSMIC-2) consists of six small satellites launched in 2019. Data from these satellites, combined with data from satellites launched by Europe, Japan, and other countries, help NOAA and its partners to further advance weather prediction, including hurricane early warning.

Partly thanks to advances in CIS services such as these, in the United States there has been a recent and deliberate shift from crisis management to proactive risk management in the area of drought and extreme weather. Congress authorized the National Integrated Drought Information System (NIDIS) program in 2006, and in 2016 President Obama signed a presidential memorandum directing federal agencies to build national capabilities for long-term drought resilience. Today, transport, aviation, farm insurance, firefighting, health, tourism, defense, retail, and many other sectors use CIS information to reduce costs and risks and boost productivity.

Information from NOAA's models and predictions also informs global understanding of drought and climate change, helping other countries in preparing for climate change and making informed decisions to reduce climate risk. For example, SERVIR (https://www.servirglobal.net/) is a partnership between NASA and USAID that utilizes NOAA's satellite and information services. SERVIR works together with other organizations globally to help developing countries use CIS and hydrometeorological systems, with a focus on managing climate risks and land use by using remotely sensed data. Flood forecasting, water resources management, agricultural decision-making and food security, land cover monitoring, and biomass estimations are all areas where SERVIR aims to help partner countries. SERVIR aims to provide decision-makers with tools, products, and services to act locally on climate-sensitive issues such as natural disasters, agriculture, food security, land-use change, water, and ecosystems and land use.

APPENDIX 2
CIS, Disaster Warnings, and the Example of Cyclone Idai in Southern Africa

CIS are not only useful for longer-term planning and risk management in the context of a changing climate. These systems can also provide valuable early warning of natural disasters such as storms and floods at much shorter timescales. CIS can also provide better understanding of how water levels, temperatures, ocean conditions, soil moisture, and other variables will behave post-disaster, making rebuilding efforts faster, better, and more resilient to future shocks.

Even small changes in the hydrosphere can have big impacts on people, particularly in poor countries. For example, in Haiti over the past decade, seventeen hurricanes have killed more than 3,600 people and affected 800,000 others. The cost of damage from Hurricane Matthew in 2016 alone was equivalent to 32 percent of Haiti's gross domestic product (GDP) (USAID 2020). The damage wrought by Hurricane Tomas in 2010 represented 43.4 percent of Saint Lucia's GDP. Between 2001 and 2008, landslides and floods in Nepal killed 1,673 people, affected 221,372 families, killed 33,365 head of livestock, destroyed 52,007 houses, and washed away or destroyed over 22,000 hectares of land.

In early March 2019, the coast of Mozambique was struck by one of the most powerful tropical cyclones ever recorded in the region. Idai had maximum sustained wind speeds of about 120 miles per hour (about 195 km per hour).[18] The flooding and catastrophic damage caused by Idai led to the deaths of more than 1,300 people in Mozambique, Zimbabwe, and Malawi and harmed more than three million other people. Thousands of homes and hundreds of thousands of acres of crops were destroyed. Damage (direct and indirect) costing at least US$2 billion has been estimated, and many development gains in this area were undone.

The Mozambican coastal city of Beira (the country's fourth largest city) was particularly badly hit. More than 90 percent of Beira was damaged or destroyed, including swaths of almost total destruction. Flooding was more than twenty feet deep in places. Infrastructure such as schools, hospitals, and clinics was badly affected, greatly hindering access to services. In the aftermath of the storm, a severe humanitarian crisis developed, including cholera and malaria outbreaks and shortages of food and shelter. The supply of clean drinking water in affected areas became a particular challenge.

Regionally integrated CIS services in southern Africa are still in development, particularly integrating warnings of extreme weather into national and regional policy and into emergency preparedness. CIS data is in different formats and is difficult to access and as a result, the full value of the various components is still not being realized (Botai et al. 2015). Detailed resolution is also variable.

The Regional Specialized Meteorological Centre (RSMC) operated by the Météo-France station on the Indian Ocean island of Réunion tracked Idai and provided updates and warnings in the region.[19] Idai was also forecast two days in advance by the South African Weather Service (Bopape et al. 2021). These updates and warnings, together with the activities of local weather forecasting and emergency services in Mozambique, Zimbabwe, and Malawi, helped prevent even wider damage and loss of life. Nevertheless, a concern remains that disaster warning information, in an accessible format, is still not always available to the most vulnerable and poorest people in the region who are usually those most severely impacted by natural disasters in the long term.

18 In the United States, this would have made Idai a Category 4 hurricane. While not the most severe category, a Category 4 hurricane almost completely destroyed the coastal city of Galveston in Texas in 1900. The Galveston hurricane, which caused thousands of deaths and remains the United States' deadliest natural disaster, boosted weather forecasting, early warning, and disaster preparedness in North America (Larson 1999).

19 RSMC is one of the organizations selected by the WMO responsible for tracking and issuing bulletins, warnings, and advisories about tropical cyclones in their designated areas of responsibility.

The damage wrought by Idai and the human and financial cost to the region illustrate the urgent need to further institutionalize CIS, in particular to extract maximum value from existing activities and datasets to improve predisaster planning and preparedness. Extreme weather events such cyclones and droughts are predicted to increase in number and severity in the region. Better CIS services, particularly those aimed at the most vulnerable, are vital to countering these threats to regional stability, economic development, and well-being.

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SCALE

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PRO-WASH

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