BACKGROUND PAPER

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SCALING CLIMATE SERVICES TO ENABLE EFFECTIVE ADAPTATION ACTION

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Executive Summary

Adaptation to anthropogenic climate change is the biggest challenge that humankind faces. The Intergovernmental Panel on Climate Change (IPCC) provides a synthesis of the state of the science, impacts, and policy, with a focus on long-term climate trends. However, the worst impacts of climate change are likely to come from its exacerbation of weather and climate variability. For example, higher temperatures in a particular region could lead to harsher droughts and more deadly heat waves. These are also the kinds of hazards that are regularly monitored and forecast by governments and institutions at the national, regional, and international scale.

This paper argues that climate services are a critical component of adaptation. Communities that benefit from climate services will be better adapted to long-term climate change as well as the weather events and the year-to-year variability it could make worse. Climate services involve the production, translation, transfer, and use of climate knowledge and information in relevant decision-making, policy and planning[a]. They involve far more than climate data, encompassing an understanding of the needs of decision makers and delivering useful information in ways it can be applied for better results. A well-functioning climate service can help decision-makers understand, anticipate, and manage climate-related risks across the range of relevant time scales, from days to decades, much in the way a national meteorological service (NMS) does for weather. Yet, in most of the world, climate services are not sufficiently developed, nor are they properly aligned with the needs of decision-makers in the sectors and systems that are most at risk. The urgency of the climate challenge calls for a critical examination of the current state of climate services relative to the needs of decision-makers; it also requires aggressive action to address long-standing obstacles to meeting those needs. While several decades of research, investment, and implementation provide a strong

[a] http://www.climate-services.org/about-us/what-are-climate-services

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foundation for climate services, more deliberate action is needed to position climate services as essential to adaptation. The actions are organized under four areas of recommendations:

- **Align climate services with decision-maker needs;**
- **Improve the usability of nationally produced climate information;**
- **Consolidate knowledge and expertise; and**
- **Mobilize and align investment to strengthen climate services.**

1. Introduction

Socio-economic development and human well-being have always been tied to our variable and changing climate. While current climate risks continue to challenge society's ability to cope, climate change threatens to impede and undo development gains: by increasing the frequency and severity of extreme events, shifting suitability zones for crops and diseases, and endangering coastal areas with sea-level rise. These threaten essential sectors such as agriculture, forestry, water resources, tourism, transportation, energy, and health. The global community has acknowledged and committed urgent action to manage climatic risks through three landmark intergovernmental agreements: the 2015 Paris Agreement of the UN Framework Convention on Climate Change (UNFCCC), the Sustainable Development Goals, and the Sendai Framework for Disaster Risk Reduction.

In order to manage risks, we must understand what they are and be able to anticipate them. Climate information has the potential to inform a range of both short- and long-term decisions, contributing to the resilience of governments, organizations, and individuals to current climate variability while also preparing for an uncertain future that may look very different from today.[1] Producing climate information and ensuring it is available and usable for decision makers is the role of climate services – a foundational but sometimes overlooked part of the enabling environment for adaptation efforts. The urgency of the climate challenge calls for a critical examination of the current state of climate services relative to what is known about the needs of decision-makers across climate-sensitive sectors, and aggressive action to address long-standing obstacles to aligning climate services with those needs.

This discussion paper provides a critical assessment of the current state of climate services in the developing world, and a road map for aligning and strengthening climate services to enable effective adaptation action at scale. Following a discussion of climate services concepts, the paper discusses the role of climate information in national adaptation planning, and challenges and opportunities for climate services to support adaptation of several at-risk systems, drawing on experience from agriculture and rural livelihoods, and from infrastructure. Four key challenges are discussed: (a) appropriateness of services to decision-maker needs; (b) improving the usability of nationally produced climate information; (c) consolidating knowledge and expertise; and (d) mobilizing and aligning investment to strengthen climate services. For each of these challenges, we identify priority near-term actions that aim to overcome long-standing obstacles and enable climate services to support adaptation at the scale of the challenge.

2. Climate Information and National Adaptation Planning

The National Adaptation Planning process offers an opportunity for developing countries to articulate needs and identify funding sources for climate services. National Adaptation Plans (NAPs) grew out of the UNFCCC negotiating process as a means to help developing countries address adaptation needs in a holistic way. NAPs are now recommended for all countries. The objectives of NAPs are to reduce vulnerability to climate-change impacts by building adaptive capacity and resilience. The process encourages countries to integrate climate change into national decision-making by building on existing adaptation activities. Although the UNFCCC process initially treated climate change as an environmental issue—and enlisted ministries of environment as lead agencies—the NAP process aims to treat climate as a risk to economic sectors, and to integrate adaptation efforts with existing efforts related to economic growth, agriculture, infrastructure, and other climate-sensitive development.

The foundational role that climate information plays in adaptation is often not reflected in national adaptation priorities and strategies. However, guidelines developed by the UNFCCC Least Developed Countries Expert Group (LEG) highlight the need to use relevant climate data to design and implement adaptation measures, providing an opening for incorporating climate-service investment into adaptation plans.[3] The process laid out in the LEG guidelines – identifying available information on climate impacts and vulnerabilities, addressing the data and human capacity required for these analyses, and considering these analyses to prioritize adaptation actions in response to the most important climatic risks – clearly requires investment in both climate services and the technical leadership of national meteorological services. However, the ministries and stakeholders involved often limit the application of these guidelines to the consideration of climate-change information and impacts. They put significant efforts into looking at much longer timescales, while overlooking shorter timescales of climate information that can help address more immediate impacts. However, few governments are in a position to plan or make investments that could be reasonably informed by late-century climate-change projections; the timescale of climate information considered in NAPs should match decisions that the NAPs can reasonably influence.

With the UNFCCC Paris Agreement, adaptation emerged as an equal priority to greenhouse-gas mitigation, reflecting the urgency of the IPCC's Third Assessment Report, which drew attention to the inevitability of significant climate change regardless of mitigation efforts.[4,5] In the early years of the UNFCCC process, there was much discussion of the need for downscaled climate projections to inform adaptation planning.[6] Vulnerability assessments, modeled on the IPCC's Working Group 2 assessment approach, were seen as a first step in adaptation planning. More recently, there has been a growing recognition that IPCC projections are not useful for much adaptation planning, due to both a mismatch of timescales and the uncertainty inherent in late-century projections. The role of vulnerability assessments in NAPs and for a growing pool of climate finance innovations, continues to fuel demand for increasingly fine-scaled climate-change projections. However, few, if any, adaptation decisions have planning horizons that extend to the end of the century. This has had the unfortunate consequence of generating interest in and expending resources for downscaled climate projections in support of planning and decision-making that cannot readily take in such information. Even in the case of infrastructure planning, there is little use for climate outlooks beyond 20-30 years into the future (see 3.2).

National meteorological services in developing countries tend to be inadequately funded and politically weak relative to other national agencies. The NAP process offers a way to demonstrate that NMSs are critical to the success of ministries and agencies overseeing major sectors of the economy as well as highlight the cost to adaptation and development efforts if these services are not adequately funded. Experiences in Jamaica (Box 1) and Uruguay (Box 2) illustrate ways that ministries responsible for climate-sensitive sectors can work with their national meteorological services to co-lead the development of climate services and ensure they are adequately funded.

3. Use of Climate Information for Adaptation and Resilience

The impacts of climate change don't come only through gradual changes in average conditions, but also through changes in the frequency and intensity of extreme conditions. Adaptation to climate change therefore involves using information to manage climate-related risk at a range of time scales. Regardless of the quality of information being provided, climate services do not contribute economic or social value unless users benefit from better decisions as a result of the information.[2] If they are to be used, climate services must be tailored to the needs and contexts of specific decision-makers, and mainstreamed into their planning and operations. This involves accounting for key differences among sectors and systems, such as:

- The most pressing climate-related risks;
- Capacity of a sector to act on information;
- The extent to which decision-making is centralized or decentralized;
- The dominant time and spatial scales of decisions;
- The tolerance of an action or decision to the different levels of uncertainty associated with different types of information; and
- The policy context for climate sensitive decision-making.

Furthermore, decision-makers are generally more interested in impacts and management options within the systems they are managing than in meteorological

BOX 1 Drought early warning for farmers in Jamaica[7-9]

Photo: Elisabeth Gawthrop (IRI)

During a national climate policy development workshop, a number of agencies in Jamaica's government cited lack of information as an impediment to adaptation. In follow-up efforts to improve climate services in support of key economic sectors, USAID and IRI partnered with Jamaica's meteorological service (JMS) to improve its ability to meet decision-maker needs. Resource constraints limited JMS's ability to meet all demands for services, but failure to meet those demands adversely impacted the agency's budget. To break this cycle, USAID offered to support JMS to deliver one tool for one powerful government stakeholder, with the intention that this stakeholder would help JMS secure more funding. Stakeholders agreed to prioritize farmers' management of drought risk, and the Rural and Agricultural Development Agency volunteered to work with JMS to co-develop a drought early warning service for farmers. The resulting service (online at https://www.jamaicaclimate.net/) consists of the seasonal drought forecasting system, forums to raise farmers' awareness and capacity, and information delivery through text messages.

quantities such as precipitation and temperature. This calls for the translation of historical data, forecasts and other types of climate information into more decision-relevant information, analyses or advisories. While an understanding of the local climate and its impacts is necessary for adapting to a variable and changing climate, it is not sufficient. Climate information is just one of many factors in decision-making. Experience from agriculture and rural livelihoods, and from infrastructure planning and management highlights how the context shapes climate service needs, and some of the opportunities for climate services to meet context-specific adaptation needs.

3.1 Food security and rural livelihoods

Agriculture is the main source of livelihood for the majority of people in the developing world. It is also one of the most climate-sensitive sectors. Smallholder farmers, pastoralists and fishers are among those most vulnerable to the impacts of the variable and changing climate. Climate variability is a major contributor to food insecurity and an impediment to efforts to improve the livelihoods of smallholder farmers. The coping strategies that farm households employ in the face of extreme events, such as droughts and flooding, can erode their capacity to build a better life by depleting their productive assets and human capital, while the uncertainty associated with climate variability is a disincentive to investing in agricultural innovation.[10,11] Within farming communities, the impacts are borne disproportionately by the poorest members.[12,13] The actual impact of unanticipated shocks, and the potential impact of climate uncertainty on agricultural decision-making and investment contribute to poverty traps that lock many farmers in climate-vulnerable livelihoods.[14–17]

Climate Smart Agriculture (CSA) is an approach to reorienting agricultural systems to achieve food security, build resilience and contribute to greenhouse gas mitigation.[18] The widespread adoption of the CSA concept over the past several years coincided with a shift in emphasis from adapting to future climate to building resilience to current climate risk. Although climate-change projections are still used widely for adaptation policy and planning in agriculture, seasonal forecasts and analyses of historical data have dominated the development of operational climate services to support agricultural production. Most climate-sensitive agricultural production decisions have time horizons ranging from seasonal (for annual crops) to about a decade (for perennial crops). Local scale information is crucial for agricultural production decisions; although larger spatial scales are important for anticipating market prices, and for planning trade and food security interventions. Because the agricultural sector includes many decentralized, often remote individual decision-makers, agricultural climate services placed heavy demands on effective communication processes to "reach the last mile," and build the capacity of farmers to act

BOX 2 Agricultural adaptation in Uruguay's agriculture sector[19-21]

In 2010, Uruguay's Ministry of Agriculture embraced an adaptation approach based on building resilience to climate variability and improving climate risk management for agriculture. A World Bank project called "Development and Adaptation to Climate Change," created the National Agricultural Information System (SNIA) to support both climate-informed decisions in the private sector and elaboration of public policy. SNIA integrates information from Uruguay's National Meteorological Service (INUMET), several of the Ministry's departments, and international institutions into decision support tools for agriculture. During a severe drought in 2015, the Ministry used SNIA information to declare an emergency in some counties, triggering financial assistance to the most vulnerable farmers. SNIA allowed the Ministry to use objective and information to justify what could have been a politically charged and potentially disputed decision. See: http://snia.gub.uy

Photo: Francesco Fiondella (IRI)

effectively on information and intermediaries to support that process (Box 3). A common sentiment among agriculture ministries and farmer support networks is that information should meet the specific needs of farmers, and be tailored geographically and by farming system. Beyond a forecast or early warning system, farmers need to have options enabling them to change their behavior based on the forecast. This may mean access to irrigation or other sources of water, access to different seed varieties, or access to insurance. Adaptation is a multidisciplinary process, and the meteorological services must work with other disciplines to provide support for the agriculture sector.

Agricultural research and practice have a relatively strong history and well-developed body of knowledge on the use of weather and climate information. This community led the early development of climate services in parts of the developed world, particularly Australia. Farmers' awareness of climate risk and experience in routinely making decisions in the face of uncertainty help them to be receptive to probabilistic climate information. In most developing countries, national meteorological services (NMSs) are the main source of climate information for agricultural decision-making. However, there are widespread gaps between the needs of local agricultural decision-makers and the information NMSs routinely provide (see 5.4). Private information providers are playing an increasing role in some regions, primarily at a weather time scale. While private sector actors sometimes add value by bundling information with other services such as input supply and financial services, they sometimes seek to compete with NMSs.

3.2 Infrastructure planning and management

Climate-sensitive infrastructure includes buildings, transportation systems, water supply, drainage and waste systems, energy (including hydropower and other climate-dependent renewables), and communications networks. Resilient and reliable infrastructure is essential for economic development. For example, it enables the transport of goods and people, the provision of energy, clean water, communication services, and emergency response to disasters. Infrastructure investment is often an integral component of a broader national development effort, such as food security, agriculture, or public health. Because infrastructure can be costly and is often built to last for decades, these assets may sometimes be particularly sensitive to climate change.

Infrastructure is the adaptation context most closely associated with long-term planning at the time scale of climate-change projections. However, as with other climate-sensitive sectors and systems, the time scale of the information should be tailored to the varying time horizons of decisions. Design decisions for infrastructure such as large dams and large-scale drainage and water

BOX 3 Developing climate services for Rwanda's farmers[22]

The USAID-funded Rwanda Climate Services for Agriculture project invests in capacity building for both the supply and demand sides of climate services. The project adopted the face-to-face Participatory Integrated Climate Services for Agriculture (PICSA) process developed by the University of Reading (https://research.reading.ac.uk/picsa/), as the primary delivery mechanism for farmers and integrated it into Rwanda's Twigire Muhinzi agricultural extension service. As of May 2019, 1,825 trained extension workers trained and facilitated more than 130,000 farmers around the country to access, understand and use climate information. Initial evidence indicates that more than 90% of participating farmers adjust their management practices as a result, and perceive livelihood, food security and social benefits. Biweekly climate services radio programming is also accessible by 70% of the population. The project also used IRI's ENACTS approach (Box 5) to help Meteo-Rwanda overcome significant data gap challenges resulting from the genocide. Meteo-Rwanda now provides a rich suite of gridded historical and downscaled seasonal rainfall forecast products through online interactive maps.

Photo: Francesco Fiondella (IRI)

supply infrastructure are fixed for an extended period, with scope for only minor adjustments (e.g., raising walls and rebuilding sluiceways) once construction begins. For most infrastructure, planning horizons are on the order of 10-25 years, even if the expected life span is much longer. For buildings, the structure itself should last a century or more, but the climate sensitive components – roofs, heating and cooling – are typically replaced every 20-25 years. A road that is designed to last for ten years before requiring major maintenance is considered a success. At the other extreme, siting of major climate-sensitive infrastructure should consider potential threats such as sea-level rise or changes in precipitation about 50 years into the future. This is because public infrastructure tends to attract infrastructure – for example, communities and businesses grow up around roads – and the potential consequences of long-term threats are much higher for communities and industries than for individual buildings or roads. Design decisions have relatively long-time horizons. However, once the infrastructure is built, decisions around operations and maintenance become dominant. Hydropower management increasingly relies on short-term river flow forecasts to project and manage hydropower outputs and plan maintenance.

Infrastructure design is strongly rooted in engineering design standards. Because of concerns about liability and public responsibility, these standards tend to be long-standing and conservative, and only rarely reevaluated. For infrastructure, there are no global design standards or universal guidelines on the use of climate information. National standards are not uniform across developing countries. The standards actually used are often set by development banks, or donor countries such as China, who fund major infrastructure projects. Developing countries must balance their aims for robust infrastructure with the desire of the funding country to keep costs low. The use of rainfall data over some historical period is well established in standards for climate-sensitive infrastructure such as storm water drainage systems.

There is often resistance to deviating from engineering design standards based on uncertain climate projections or evidence of recent change. This is because existing safety and performance margins are expected to accommodate modest changes in climate statistics, and because further over-designing infrastructure to accommodate a worst-case climatic future may be very expensive and compromise spending in other areas. On the other hand, the small number of actors dominating much of infrastructure construction might offer an opportunity to introduce new applications of climate services to infrastructure design, construction and operations. Efforts to better account for changing climate risk, following Cape

BOX 4 The 2017-2018 Cape Town water supply crisis

After experiencing three years of below-normal winter rainfall, Cape Town's dam levels were so low it appeared likely the city's water supply system would fail in 2018. A strong public response reduced consumption enough to avert catastrophe. Engineering consultants and University of Cape Town researchers who were tasked to model potential climate change impacts noted several challenges:

- Trends evident in climate projections are incompatible with deeply held assumptions information used in water engineering practice.
- Stochastic modeling tools for water supply weren't designed to represent multi-year droughts.
- Technical constraints greatly limited the proportion of climate model runs incorporated into water supply models.

Theewaterskloff Dam, South Africa, 1 January 2017. Image processed by Sentinel Hub

This led to a custom methodology that shifted the focus from the modeling framework to the underlying problem, and represented an acceptable compromise between scientific rigor favored by the university climate and hydrology experts, and the design tools and practices favored by the engineering experts.

Town's 2017-2018 water crisis (Box 4), reveal some of the issues that need to be addressed to factor climate information into the design and management of major public infrastructure.

4. Climate Services

4.1 Concepts

The state of the atmosphere varies on a continuum of time scales, all of which impact society and impose challenges to decision-making (Fig. 1). *Weather* refers to the state of the atmosphere at any given time. *Climate* refers to the statistics of weather such as long-term averages, the probability distribution around the average, seasonal changes, and any long-term trends. It is useful to distinguish between *climate variability*, which occurs on time scales from year-to-year to multiple decades, and *climate change*, which refers to changes over decades to centuries that are caused largely by human action.

Because global warming associated with human activity interacts with natural climate variability, the important threats from climate change often come through shifts in the frequency and severity of extreme events. For example, the gradual rise in global sea levels increases the area inundated and resulting damage from the storm surge of individual cyclones.[23,24] The interaction of incremental increases in average temperatures with natural variability has resulted in deadly heat waves that would have been extremely unlikely without climate change.[25] A significant warming trend is apparent in temperature records from recent decades over much of the world. However, for rainfall, most of the observed variability in the data is due to either year-to-year (60-80%) or natural low-frequency decadal variability (15-50%), while long-term trends associated with climate change account for at most a few percent of the variance we see in the records (Fig. 2). Historical data are crucial for understanding the variability, seasonal patterns and any trends that characterize the local climate, and for evaluating and interpreting predictions about future climate conditions.

Uncertainty is a fundamental feature of the climate. Because the atmosphere is a non-linear, chaotic system, daily weather can be predicted from the current state of the atmosphere to a maximum of about two weeks into the future. Predictions at longer time scales are possible, although with greater uncertainty, because of atmosphere interactions with the underlying ocean and land surface (which vary more slowly) and with changing atmospheric composition and its effect on the global heat balance. The degree of potential predictability varies by lead time, and geographically for a given lead time. The climate system is characterized by irreducible uncertainty, which generally increases with increasing lead time. Improvements in climate science, predictive models and data cannot eliminate this uncertainty. The uncertainty of forecasts at a seasonal lead time can be described and calibrated in probabilistic terms by comparing the predictions with the observed data. However, the uncertainty of longer-term climate change projections cannot be calibrated or characterized directly by comparing predictions with actual climate realizations, resulting in an unquantifiable uncertainty.[26]

Because people experience weather daily, it is a relatively simple concept to understand and factor into decision-making. Less so with climate, which is an abstract statistical concept and is inherently probabilistic. The information becomes more uncertain and hence more complex as lead time increases from a timescale of *weather* to *climate variability* to *climate change*. Furthermore, the human mind uses a different processing mode ("analytical processing") when information is obtained through statistical description, and has more difficulty interpreting and incorporating that information into decisions, than when information is obtained through repeated experience ("experiential processing").[27–29] For these reasons, climate information is much more challenging than weather information to understand, and requires different communication processes and more support to use appropriately.

To be effective, climate services require substantially more than just adding information at climate time scales to existing weather services. Information must match the needs of decision makers and be translated for their use, then communicated to them in a timely and accessible fashion. To capture these multiple facets, climate services are often described as a value chain that requires expertise from multiple disciplines and actors.

4.2 Roots of climate services

Although the term climate services has been widely used for only a little more than a decade, the field of climate services has grown out of several decades of research and implementation within three distinct communities: those engaged in the development of seasonal climate prediction, those engaged in the development and use of climate information within climate-sensitive sectors, and those engaged in climate-change projections and UNFCCC/IPCC processes.

These communities bring different approaches to climate services. For instance, the seasonal forecasting and climate change communities have emphasized predictive models that normally operate at large spatial and temporal scales, and their use of historical climate data has largely been limited to the calibration and verification of their models. Where research and practice have been led by the climate-sensitive sectors, climate services have emphasized supporting decision-making and tended to make greater use of local historical and monitored climate observations, alone or in combination with predictions. This community also focuses more on translating climate information into local impacts and context-specific response options. In agriculture, for example, the systematic use of climate information for agricultural risk management can be attributed in part to pioneering work in northeastern Australia in the late 1980s and 1990s, which relied heavily on analyses of local daily data to quantify risks, and the use of systems modeling and decision support tools to translate climate information into agricultural impacts and management options.[30–32] Climate change models, used in IPCC assessments, were not originally intended for use in

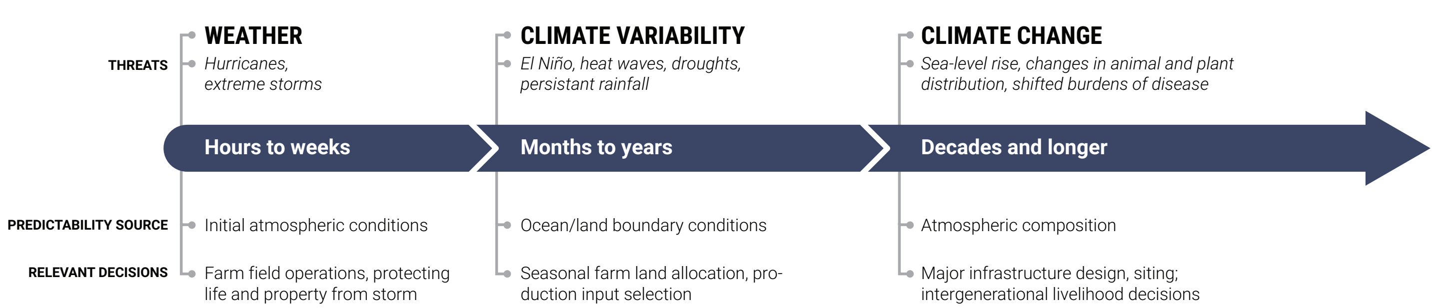

Figure 1. Time scales of atmospheric variation, information, and climate-sensitive decisions.

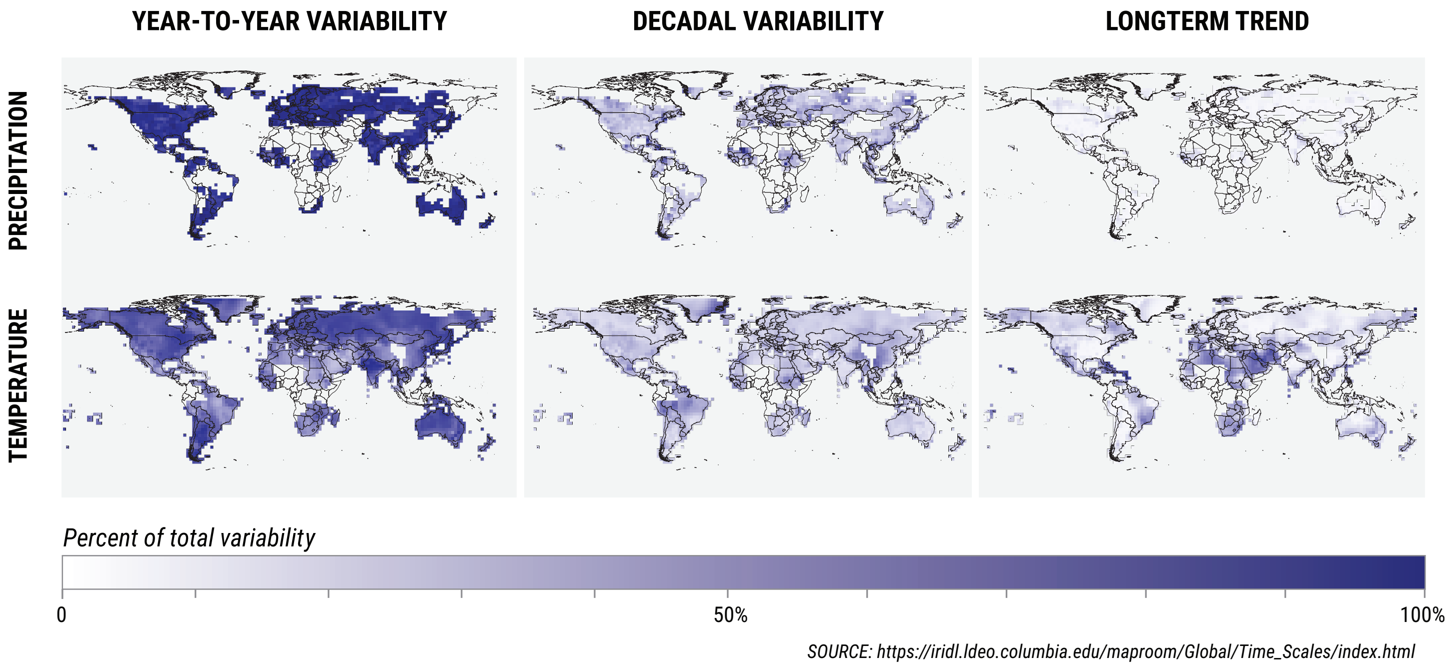

Figure 2. Percent of the observed total variability for both precipitation and temperature explained by the long-term trend, decadal variability and interannual variability.

adaptation decision-making. Climate research institutions and operational centers in developed countries still dominate the provision of climate change projections.

The approaches of NMSs in the developing world reflect those of the seasonal prediction community more than those of the climate change modeling or sector-focused groups.[33] The multiple roots of climate services, and changes in terminology over time, have contributed to coordination challenges and to fragmentation of knowledge about climate service good practice.

4.3 Major climate service initiatives and actors

At the country level, NMSs have the primary responsibility to provide observed and forecast weather information, climate information, and warnings of impending hydroclimatic threats. At the global level, the UN World Meteorological Organization (WMO) coordinates and supports NMSs to fulfill this mandate. WMO also coordinates 13 Global Producing Centers for Long-Range Forecasts, and an evolving global network of Regional Climate Centers (RCCs), each of which supports its set of member countries with seasonal forecasts, climate monitoring, data services and training.

Since their inception in 1997, regional climate outlook forums (RCOFs) have been a focal point of international efforts to support the production and use of seasonal climate forecasts across the developing world.[34,35] These periodic forums are hosted by RCCs and timed shortly before the start of major rainy seasons. They include trainings for NMS staff, a process to compare predictions and produce a consensus regional forecast for the upcoming season, and a public event in which the forecast and its implications are presented to a range of stakeholders from participating countries.

Operational weather and seasonal forecasts and analyses based on historical observations come largely through the NMS, with the support of WMO and RCCs. A different set of actors and processes drive longer-term climate change projections, however. In particular, IPCC plays a coordinating role with a network of climate modeling operational and research institutions, which generate projections based on climate models driven by future greenhouse-gas scenarios. These climate change projections feed into the IPCC's assessments. The Coordinated Regional Climate Downscaling Experiment (CORDEX), an activity of the World Climate Research Program (WCRP), coordinates regional downscaling of climate change models. CORDEX objectives include advancing understanding of regional to local climate phenomena, evaluating and improving climate downscaling techniques, producing a coordinated set of regional downscaled climate change projections worldwide, and fostering exchange with users of regional climate information.

The climate research that underpins climate services benefits from a degree of coordination and facilitation globally through the WCRP. There is, however, a gap in coordination mechanisms for the dimensions of climate services that fall outside of climate science. In an attempt to fill that gap, the Climate Services Partnership (CSP) was launched in 2011.[36] The CSP was formulated as an informal network of climate information users, providers, donors and researchers. It has made progress in convening this community to share knowledge through its International Conference on Climate Services series, and advanced the agenda on issues such as economic valuation and ethical standards.[37–39]

Beyond these global initiatives and several strong regional networks, the institutional landscape that supports climate services in the developing world is heterogeneous and at best weakly coordinated. Actors include donors funding a dynamic set of time-bound implementation and capacity development projects, a research community spanning the supply and demand sides of climate services, a growing set of development organizations responding to increased donor support, and an increasing number of private sector weather and climate information providers.

5. Effective Climate Services for Adaptation

Decades of research, investment and implementation provide a foundation for climate-informed decision-making, but the urgency of the climate challenge calls for more aggressive action to overcome longstanding gaps and to position climate services to better inform adaptation across systems at risk and at the scale of the challenge. The required actions fall under four key areas:

(a) align climate services with decision-maker needs;
(b) improve the usability of nationally produced climate information; (c) consolidate knowledge and expertise; and (d) mobilize and align investment to strengthen climate services.

5.1 Align climate information and services with decision-maker needs

If climate services are to inform decision-making, they must be responsive to the needs of decision-makers. Effective climate services require dialogue between users and providers of climate information. But for the dialogue to lead to improved services, decision-makers must be equipped to understand and express their information needs, and information providers must be responsive and accountable to those needs. There is a critical need to balance investment in climate science and climate information supply, with investment in the capacity and engagement of users of that information, and the institutions and networks in which they are embedded.

Once this dialog is possible, one concept becomes readily apparent: the climate information should be relevant to the timescale of the decision and/or its impact. Long-term climate change projections are often unsuitable for adaptation planning because few adaptation decisions extend beyond 20 years. Even if a decision calls for end-of-century information, unquantifiable uncertainty in future projections, and a poor match with the timescales of most adaptation decisions may severely limit the usability of projections. Climate-change projections are easily misused and, at worst, contribute to maladaptation. While development agencies and investment institutions have become more sophisticated in their use of climate information recently, the issue is still pervasive enough to require attention.

CHALLENGES

Engagement and co-production

The climate services community has long recognized that dialogue between users and providers of information is essential if the information is to be used in decision-making.[34,40,41] In principle, involving users in co-production should ensure that those services meet their needs. However, weaknesses in the engagement processes, or capacity constraints on either the supply or the demand side can become barriers that prevent co-production efforts from improving climate services.[42]

It matters who participates in the co-production process. Co-production of climate services is too often narrowly framed as a bilateral relationship between climate science and end-users, overlooking the sector-specific research, institutional, and policy environments in which those end-users are embedded. Co-production practice cannot be expected to strengthen climate services if it excludes actors who are crucial for the translation, communication, and use of those services.[42] Co-production can also be rendered ineffective if actual and potential users of climate services are misidentified, or if groups of decision-makers are either overlooked, or disadvantaged by power dynamics.[43]

The way interactions are structured can be a barrier to effective climate services. Top-down interaction can fatigue stakeholders and undermine the climate services endeavor when climate information providers focus on educating users, or when "extractive" interaction formats elicit feedback while providing participants with little in return.[44] One such example comes from the city of Cape Town, where a history of negative interactions with well-meaning scientists has led city officials to require evidence of mutually beneficial outputs before engagement can take place. Productive interaction processes are described along a spectrum, from consultative processes – relatively streamlined to tailor planned information products to user needs -- to immersive ones that aim for sustained interaction and networks, and equitable knowledge sharing.[45,46]

Even when interactions are managed well, for co-production to improve climate services the decision-makers must have the capacity to articulate demand for products and services that might not yet be available, and climate information providers must be responsive and accountable to those needs. A recent paper[42] makes the case that the main conclusion of a multi-stakeholder, cross-sectoral assessment of the use of climate information in Africa published in 2006[47] still holds: that such demand-side and supply-side capacity constraints are widespread, and reinforce each other in a manner that impedes the development and effective use of climate services. To the degree that this diagnosis holds true, these mutually reinforcing constraints must be addressed in parallel if engaging decision-makers in co-production is to actually align climate services with their needs.

Climate Information

There are significant risks when climate change projections are used to guide and justify adaptation decisions for which they are not well suited. The original purpose of end-of-century climate change projections, developed under the auspices of the IPCC, was to weigh the evidence for human-induced climate change and inform policies to mitigate greenhouse gas emissions. Increasingly, these projections are used to inform and justify national and local adaptation strategies with much more detailed information than the models were designed to provide, such as changes in the frequency and severity of climate extremes at a local scale.[48,49] The explicit or implicit need to justify climate funding requirements with such analyses, and the internal climate screening requirements of several major funders,[50] contribute to the continuing demand for impact studies based on downscaled, end-of-century climate change projections.[26]

A substantial number of adaptation planning horizons reach out 10-30 years, such as infrastructure design and agricultural value chain development. Significantly fewer look to the end-of-century, but still many academic exercises have investigated how late 21st century climate may affect crops, water resources and diseases with little regard for how well these tools perform. Climate change projections available on near-term (10-30 years) timescales have substantial limitations, in part because natural decadal variability may dominate trends over 10-30-year periods. In practice, climate change projections for mid-century are easily misused. Uncertainty is downplayed, often at the same time that higher-resolution, downscaled projections are provided. Uncertainty over a particular area will increase as that area gets smaller, which is what happens with downscaled climate data. That uncertainty is just carried forward when fed into models of impacts, such as sea level rise, or agricultural production.[51] Downscaling gives misleading appearance of more precise local information, while actually reducing the level of confidence of the information.[26,52]

Second, the worst impacts of climate change are likely to come from the exacerbation of weather and climate variability, particularly extremes. For example, the upward trends in temperatures will cause more severe drought conditions by increasing evaporation from the soil. Climate models tend to poorly represent natural variability and climate and weather extremes. On the 10-30 year timescales, which are most relevant for long-term planning, decadal variability is particularly important and cannot be anticipated using climate change projections.[53,54]

Finally, although climate models capture some important aspects of the changing climate system, evaluations have shown that major errors exist, including in the magnitude and–for rainfall–even the direction of recent climate trends in some parts of the world. For example, all of the models used in the last IPCC assessment underestimate the increase in rainfall observed in Southeastern South America in past decades, with several models simulating negative trends.[55] In East Africa, coupled climate models systematically underestimate the long rains and overestimate the short rains.[56]

Unfortunately, the presentation of climate change projections rarely makes explicit the limitations of this information and their consequences for decision-making.[33,52,57] Climate change projections are generated by a number of global climate modeling centers, in coordination with the IPCC assessment process. Demand for detailed, downscaled climate change projections to support local adaptation planning and access climate finance has resulted in a proliferation of online portals, with no accepted standards of good practice. These online portals disseminate climate model output widely, but usually with little consideration of uncertainties or how the information will be understood and used.[33]

Several researchers have raised concerns that uncritical use of climate change projections to guide local adaptation planning and investment may lead to maladaptation, particularly where models exhibit significant biases in simulating the recent climate.[26,33]

OPPORTUNITIES

Engagement and co-production

A high priority for improving the contribution of climate services to adaptation is to **invest in the capacity of decision-makers in climate-sensitive sectors to use climate information effectively, identify their information needs, and strategically drive the co-production of climate services (Recommendation 1)**. This will require investment in training programs for government officials and other key decision-makers working in planning, agriculture, public works, public health, natural resource management and other at-risk sectors. This will also require attention be given to primary through university education and media engagement in order to build climate knowledge in the general population.

The development of effective climate services beyond a pilot scale generally involves new arrangements between NMSs and institutions affiliated with climate-sensitive sectors. Additionally, climate services and climate adaptation are typically managed by different parts of government, but those must be brought together for effective adaptation. New collaborative processes are needed for translating, communicating and using climate information for decision-making.

In several countries, national or sub-national working groups, composed of representatives of the NMS and various user groups, aim to play an intermediary role horizontally among national ministries and agencies, and vertically between national service providers and local communities.[21,58–60] Regular and sustained boundary spanning, by expert institutions or networks that work at the interface of supply and demand of information, has proven effective at aligning climate services to decision-maker needs by overcoming capacity constraints and facilitating dialogue and knowledge exchange.[34,40,41,61,62] As relatively neutral actors, external boundary organizations are sometimes able to catalyze more effective communication across institutional silos within a country.[34]

Practical mechanisms to maintain interaction among institutions engaged in climate services include establishing climate centers or focal points (used by International Federation of Red Cross and Red Crescent Societies, World Bank, World Food Program) and staff exchanges. Local universities, which are already mandated to broker knowledge and build capacity within the country, are often well positioned to broker dialogue between decision-making communities and government service providers. In Bangladesh, the Bangladesh Academy for Climate Services (BACS) creates a space for dialogue and coordination among information providers, user groups and intermediaries working on climate services, allowing for the development of demand-based trainings tailored to specific user groups and sectors, and facilitating their engagement with information providers in the co-production of improved services (Box 5).

While the specific mechanisms employed will vary by country and sector, sustained, effective co-production at scale requires high-level co-ownership of the process by the climate-sensitive sectors, accountable iterative processes, and arrangements that are formalized in policy and strategy. The second recommendation is therefore to **promote, guide and invest in the development**

BOX 5 Bangladesh Academy for Climate Services

The Bangladesh Academy for Climate Services (BACS), launched in 2018, aims to ensure that actionable climate services information is delivered to decision makers, by:

- Convening open trans-sectorial and multi-stakeholder dialogue on climate services;
- Developing tailored certification short courses for students and early- to mid-level professionals to help address identified needs; and
- Creating graduate curricula to train a new generation of weather, climate and sector experts with the skills needed to face the uncertainties of the coming decades.

Dannie Dinh (IRI)

BACS was founded by the International Centre for Climate Change & Development (ICCCAD) at Independent University, Bangladesh (IUB); International Research Institute for Climate and Society (IRI) at Columbia University; the International Maize and Wheat Improvement Center (CIMMYT); and the Bangladesh Meteorological Department (BMD). See: www.gobeshona.net/bacs

of formal institutional and policy arrangements that sustainably support climate-sensitive sectors to engage their National Meteorological Services in co-production (Recommendation 2). These arrangements can be fostered through a combination of policy "push" facilitated by the Global Framework for Climate Services (GFCS), and policy "pull" through national adaptation and development planning. With guidance and technical support coordinated by the WMO, expansion of national climate service policy frameworks and associated multi-sector institutional arrangements under GFCS provides a promising entry point to help countries remove institutional barriers, and formalize boundary spanning processes that bring users into climate service implementation at a national scale. Increased investment and technical assistance for the GFCS is needed to support national climate services frameworks and effective and sustainable co-production processes. With appropriate technical support, national adaptation and development planning processes can be used to guide line ministries and agencies of climate-sensitive sectors to proactively identify their climate service needs and engage their NMS to meet those needs.

Climate Information:

Fostering good practice in the provision and use of climate information, including climate change projections, for adaptation planning calls for interventions on both the demand and the supply of information.

Since climate change will primarily be felt through changes in variability and extreme events, climate services that support resilience are a critical part of any adaptation plan. Such services target risk assessments and predictions of weather and year-to-year climate variability, which are both much more reliable than climate change projections and more closely aligned with planning horizons.

Nonetheless, some adaptation decisions require a longer-term view. Recognizing the limitations of model-based climate projections and the risks of their misuse, a small but growing number of practical examples offer several alternative approaches for making long-term adaptation decisions.[63–66] Rather than trying to optimize adaptation strategies around projected future climate conditions and impacts – sometimes referred to as a "top-down" or "predict-then-act" approach – the overlapping approaches in Table 1 (adapted from Walker et al., 2013)[66] start with the adaptation decision and available options, and assess how vulnerable these options would be to a range of plausible future climate conditions. A *robust* strategy aims for outcomes that are acceptable, by some defined criteria, across a wide range of plausible future scenarios.[51] A *resilience* approach aims to build capacity and mechanisms to anticipate, absorb, and recover quickly from shocks or stressors, for example through developing monitoring and early warning systems, reducing vulnerabilities, and building capacity to respond to weather and

TABLE 1 Approaches long-term adaptation planning under deep uncertainty.

STRATEGY	GOAL
Robustness	Reduce vulnerability over a wide range of possible future conditions
Resilience	Foster ability to recover quickly from future shocks
Flexibility	Plan to change over time, in case conditions change
Resistance	Plan for the worst-case future scenario

Adapted from Walker et al. (2013)[66]

seasonal forecasts.[67–69] *Flexibility* can be maintained by casting longer term decisions onto shorter time frames,[70,71] by incorporating periodic reviews that allow for revision or retrofit,[72,73] and by delaying actions until uncertainty is reduced and predetermined thresholds are reached.[74] *Resistance* is the strategy embodied by engineering practices that aim to over-design critical infrastructure to withstand low-probability, high-impact events, but this strategy can be costly as climate change shifts the likelihood and severity of worst-case scenarios.

These and other related approaches share the goal of achieving outcomes that are satisfactory across a wide range of plausible future states, rather than an outcome that would be optimal for a predicted future state of the world. While these adaptation planning approaches may consult climate change projections and impact studies, in combination with historical data and expert opinion, to identify a reasonable range of plausible future conditions, they are not dependent on the projections.[75] Although good practice is still being defined and developed, there is now sufficient basis to advise decision-makers of the risks of uncritical use of climate projections, and direct them towards the growing body of alternative approaches and case studies. The recommended intervention on the demand side is to **mainstream good practice for long-lead adaptation decision-making into key investment-related activities, including consideration of other time scales of information as appropriate (Recommendation 3)**. National adaptation planning processes, climate funds, and donor climate screening requirements contribute to perceived incentives to use downscaled climate change projections to develop and justify long-term adaptation strategies, and thus are promising entry points for raising awareness of the limitations and introducing alternatives. This recommendation also calls for continued effort to develop and evaluate improved practices for long-term adaptation planning, and to address conflicting recommendations coming from the research community. In addition, attention needs to be paid to the short-term information needs of decision-makers, from weather through sub-seasonal to seasonal forecasts. These are the time scales of climate conditions and impacts most people experience and have to manage.

Recognizing the limitations of climate change projections, alternative supply-side approaches are also needed, such as analyzing historical climate variability and change, stochastic modelling and stress-testing systems to potential changes in weather and climate. Expert judgment is needed to assess the plausibility of outcomes outside the range of future climate scenarios, based on an understanding of the large-scale drivers of local climate variability and how these drivers could change in the future.[75,76] Consensus good practice standards and guidelines are still lacking, in part because no organization currently has the mandate or legitimacy to do so. The recommendation on the supply side is to **develop and promote good practice standards and correct problematic practices, including highlighting the dangers of misuse, for the provision of climate change information for adaptation decision-making (Recommendation 4)**. The best prospect for achieving this is for an inclusive global community of practice to raise awareness of the dangers of misuse, and collectively define good practice and ethical standards for the provision of climate change projections (see Recommendations 8 and 9).

5.2 Improve the Usability of National Climate Information for Adaptation

National meteorological services face significant challenges to provide actionable climate information to their diverse stakeholders. Obstacles to the use of historical data and from long-standing seasonal forecast conventions contribute to a wide gap between available climate services and the needs of local decision-makers, and are priorities for intervention.

CHALLENGES

Across the developing world, the capacity of NMSs to provide specialized climate information products and services for decision-makers is variable. The NMSs face financial, human resource, and even political constraints. Beyond resource constraints, entrenched seasonal forecasting conventions, gaps in historical observations, and NMS policies that treat observational data as a source of revenue all work against the provision of actionable climate information.

Seasonal forecasts are the major, sometimes sole focus of climate services in many developing countries. Research and experience – studied most in the context of agriculture – reveals widespread mismatch between the needs of local decision-makers and the types and formats of information that are routinely available across much of the developing world. When the first Regional Climate Outlook Forums took place in 1997-1998, they adopted a convention that is still used and promoted by most of the twenty RCOFs in operation globally,[35] and by most developing-country NMSs. Seasonal forecasts are developed by consensus, and presented as maps showing the probability that upcoming rainfall or temperature will fall in the driest, middle and wettest thirds of the historical distribution—expressed as "below-normal," "normal" or "above-normal" terciles. While NMS are charged with downscaling and tailoring the forecasts to user needs, in practice the probabilistic information is often collapsed into deterministic statements of the most probable one or two tercile categories before it reaches the general population, e.g., "rainfall will be normal to above-normal." Widely reported criticisms from the perspective of users include: lack of information to interpret forecasts locally, arbitrary thresholds and interpretation problems associated with the forecast categories, ambiguity about forecast accuracy and uncertainty, and in some cases lack of decision-relevant information beyond average rainfall expectations.[42] Although the RCOFs continue to play a valuable role in supporting and sustaining national climate services across regions, they tend to perpetuate the status quo by implicitly endorsing the tercile convention, and by providing an NMS with subjective forecasts in a form that cannot be interpreted at local scales using the best statistical methods.[42]

Gaps in observations, and data policies that restrict their use, constrain the quality and usefulness of information that NMS can provide, including both real-time monitoring and seasonal forecasts. Long-term historical meteorological observations are the main source of knowledge about the behavior of the local climate (seasonality, variability and trends), but the observation network across the developing world is inadequate and in decline.[77–81] Furthermore, donor-driven structural reform policies that reduced public investment in national meteorological services and other government services in the late 1980s and 1990s prompted NMSs globally to shift away from sharing meteorological data as a public-good, toward restricting access to sell it as a source of revenue to cover their salaries and other operating expenses.

OPPORTUNITIES

In addition to the ongoing need to invest in NMS modernization and sustainable capacity development, we see three priority opportunities to improve the usability of the climate information that NMSs provide.

The first is to **fill observational data gaps through data rescue, data merging and strategic observing infrastructure investment, so that local data can be the basis for historical and future climate information products (Recommendation 5).** Although a long-term solution to data availability must include investment in observation infrastructure, it would take new stations decades to accumulate sufficiently long records to meet climate information needs. In the near term, viable methods for reconstructing historical records now make it feasible for an NMS to derive historical climate information at a spatial resolution that can calibrate and tailor forecasts to be more useful for local decision-making.[82] Data merging involves combining quality-controlled station data with proxies such as satellite estimates and climate model reanalysis products. Several global historical data sets are available with complete spatial and temporal coverage, based on spatial interpolation of station data,[83] proxy data such as satellite rainfall estimates climate model reanalysis products,[84] and combining data from different sources.[85] Since the amount of observational data available to global data producers is usually a small fraction of what is available at national level,[82] the quality of products that can be generated by an NMS is expected to be higher than the best available global products. WMO plays a significant role in guiding NMSs on meteorological data management, and is therefore well positioned to lead an accelerated effort to overcome data availability constraints. The ENACTS initiative (Box 6) demonstrates the feasibility and benefits of using high-resolution, merged, gridded national historical data sets as a foundation for providing locally relevant climate information products.

BOX 6 The ENACTS approach to building African NMS capacity[87,88]

Gaps in historical observations are an obstacle to producing high-quality, locally relevant historical and predicted climate information beyond pilot sites with good long-term records. The IRI's ENACTS (Enhancing National Climate Services) initiative has supported 10 African NMSs (Ethiopia, Ghana, Kenya, Madagascar, Mali, Rwanda, Senegal, Tanzania, Uganda, Zambia) to fill data gaps by merging quality-controlled station records with satellite proxy data, producing long-term high-resolution gridded historical data sets. Because meteorological services steward much more data than are available to external organizations, these national data sets are expected to be of higher quality than similar global products from advanced institutions in the Global North.[87,89] A highly customizable free software platform supports automated production of suites of derived historical, monitored and (in some institutions) forecast information, which are made available through an interactive online "Maproom" portal in the form of maps, and analyses for any user-selected grid cell or administrative boundary. Several countries (Rwanda, Senegal, Ethiopia, Mali, Madagascar) and two RCCs (ICPAC, AGRHYMET) have expanded their online Maprooms to include a range of agriculture-relevant products based on daily rainfall data analyses.

The second recommendation is to **align seasonal forecast conventions used by NMS and RCOFs, to better meet the known needs of local decision-makers (Recommendation 6).** Priorities for improving seasonal forecasts include: improving the observations and science underpinning forecasts, shifting from subjective to objective forecast methods based on established sources of predictability, using high-resolution historical data to generate seasonal forecasts relevant to local level decision-making; and presenting the forecasts as full probability distributions along with the historical climate distribution. Fostering NMSs to adopt practices that reduce the usability gap requires a combination of increased "push" from WMO, Regional Climate Centers and the climate research community; and increased "pull" in the form of more effective expressions of demand from decision-makers in climate-sensitive sectors.

The third recommendation to **strengthen national climate services is to shift national meteorological data policy from treating observational data as a source of NMS revenue, to making it available as a public good and foundational part of national climate services (Recommendation 7).** This will require changes in long-standing data policy, and to the funding models and institutional cultures behind current restrictive policies. Potential leverage points include strong advocacy by WMO, fostering "pull" from influential ministries through national and sectoral planning processes, and potentially making international climate and development finance conditional on open data policy as an aspect of good governance. Awareness of the growing climate threat, and efforts to incorporate climate adaptation and resilience into national sector policies, provide the opportunity to re-frame the NMS funding issue from the cost of investing in data, to the opportunity cost of failing to use data to support adaptation. Credible economic analyses of the trade-offs between the revenue value vs. the development and adaptation value of data would support this discussion. WMO, World Bank and USAID supported the development of guidelines to help NMSs make the economic case for sustained investment in their services.[86] A potential incremental solution would be for a ministry of agriculture or another climate-sensitive sector to fund the NMS to provide data as a public-good component of its climate services.

5.3 Consolidate climate service knowledge and experience to support good practice

Fragmentation of shared experience hampers the climate services community's effectiveness. The accumulated knowledge and experience is inaccessible for guiding investment and implementation when it is shared only within a closed institutional, disciplinary, or geographical context. This is particularly true on demand-side issues such as translation, communication, use, co-production, and governance, where good practice is still being forged. A vital but often overlooked subset of the climate services research and practitioner community comes from the climate-sensitive sectors (e.g., agriculture, health, water resources, and disaster risk reduction), and works at the interface between their sectors and climate information providers on issues such as translation, communication, co-production and evaluation in order to align climate services to decision-maker needs. Mobilizing and consolidating this community's expertise is crucial for enabling effective services.

CHALLENGES

A lack of cohesiveness within the climate services professional community contributes to fragmentation of knowledge. Several decades of concerted research and investment in climate services across much of the world have generated a wealth of knowledge about the technical, practical and institutional aspects of climate services. The climate science that underpins the generation of climate information is coordinated and broadly accessible. However, knowledge on aspects of climate services, such as translation, communication, co-production, institutional arrangements and governance, is too fragmented in the literature and institutional experience to adequately guide investment and implementation. At a global level, knowledge sharing occurs within several overlapping thematic networks working on some aspects of climate services and adaptation. But they do not cover the whole spectrum of climate services, and are not sufficiently networked with each other. As a result, functional, innovative, successful building blocks of climate services may exist in each of these spaces to address specific challenges along the chain, but fail to be assembled into a systemic, comprehensive strategy for more effective climate services.

The problem is compounded by the growing number of development organizations moving into climate services, creating incentives to compete for funds at the expense of sharing knowledge and coordinating action with other climate service actors.[90,91] Development and adaptation donors, many of whom are also relatively new to climate services, are not fully able to require and assess implementation of good practice, knowledge sharing, or coordination with other funders and actors working toward shared goals. As a result, short-term donor-funded projects reinvent existing approaches and methods, and often end without sustainable knowledge management institutions or mechanisms, making donor investments redundant or inefficient.

OPPORTUNITIES

The wealth of existing knowledge and experience represents an opportunity to consolidate that knowledge to better guide climate service implementation and investment. This requires an effort to **engage the global community of practice to consolidate existing knowledge into guidance and standards for the co-production, translation, communication, evaluation and governance of climate services (Recommendation 8).** Outputs include guidelines for good practice, professional and ethical standards, an online knowledge portal, certification, and graduate and professional curricula for practitioners across the climate services spectrum.

While all aspects of the production, translation, transfer, effective uptake of climate information (i.e., decision systems) are ripe for pooling collective knowledge and distilling it into good practices guidance, the most serious gaps are outside of climate science. Investment is required for convening a process, publishing and promoting these standards, and establishing an online knowledge platform. More important, establishing good practice guidelines and professional standards requires an organization with the capacity to access and synthesize the diffuse body of knowledge, and credibility to assess what constitutes good practice. Broad community agreement, under the umbrella of an appropriate organizational structure, is the most promising way to achieve that credibility and legitimacy. The challenge of consolidating knowledge to support good practice is therefore tied to the challenge of developing an inclusive and cohesive professional community of practice.

A priority action for mobilizing a global enabling environment for effective services is to **develop a global professional organization, and national to regional counterparts, to support an inclusive climate services community of practice to share knowledge, coordinate action, mobilize resources and influence supply of climate information (Recommendation 9).** Among existing international professional organizations and networks that address aspects of climate services, the Climate Services Partnership (CSP) is the most comprehensive and inclusive. To be more effective, its mandate would need to be expanded, its participation broadened, and staff and core activities supported at least initially by donor investment. There is also a need for organizations to convene and support climate service communities of practice at national and regional levels. A number of existing organizations and networks that deal with aspects of climate services or adaptation could be tasked with this role. The Bangladesh Academy for Climate

Services (Box 5) is a good example of an organization that was created to convene and strengthen an inclusive national climate services community of practice.

5.4 Mobilize and align investment to strengthen climate services

In addition to institutional and policy action by key change agents, most of the recommended actions for strengthening climate services require new or expanded investment in particular areas including:

- Forecasts and outlooks that align with decision-maker needs: from subseasonal to multidecadal;
- Supporting and convening a global community of practice;
- Knowledge management;
- Supporting development of effective national climate service institutional and governance arrangements; and
- Strengthening the RCOF process; and national data rescue, merging and management.

The recommendation for funders is to **mobilize, align and coordinate climate service investment to incentivize good practice, and build supply-side and demand-side capacity in a balanced and sustainable manner (Recommendation 10).** National meteorological services and regional climate centers continue to need investment, focused on strengthening their capacity to provide services tailored to the needs of decision-makers. But investment in the supply of information must be balanced with increased investment in capacity of at-risk sectors and systems to understand, translate, communicate and appropriately act on climate information; and to participate effectively in the co-production of climate services. There is evidence that weaknesses in the supply of relevant climate information and in the effective demand on the part of decision-makers can reinforce each other, and that sustainable progress therefore requires addressing supply- and demand-side capacity constraints in a balanced and coordinated manner.[42,47]

Funders are in a position to use their substantial influence to incentivize good practice, for example by requiring implementing organizations and consultants to adhere to good practice and ethical standards, and by conditioning NMS funding on openness with observational data. In some cases, the need is to correct existing incentive problems. Adaptation and development funders should ensure that their project evaluation criteria and internal climate screening rules do not encourage inappropriate use of climate change projections. Competition for funding seems to have contributed to competing claims among government agencies to have the mandate to deliver climate services to end users. In the absence of accepted good practice guidelines and professional standards, increased climate service funding has arguably contributed to a growing set of development organizations working on delivery, with limited experience or grounding in existing knowledge, and a proliferation of user-focused projects that remain at a pilot scale. This is particularly apparent for NGOs and consulting companies who seek to work with user communities on things like communication processes, needs assessment, and co-production.[92,93] The competition between NMS, online global climate information platforms and private weather and climate services is a particular concern, and requires a more proactive and coherent approach among funders.

5. A Road map for Action

Because adapting to a changing climate requires decision-makers in climate-sensitive systems and sectors to understand, anticipate and manage climate-related risks across time scales, climate services are a foundational part of the enabling environment for adaptation. Decades of research, investment and experience in providing and using climate information for decision-making, and expanding political and institutional support, provide a good foundation. Yet in most of the world, capacity gaps and entrenched weakness prevent climate services from enabling adaptation at the scale of the climate challenge. This report offers ten recommendations to address five key challenges (Table 2). These recommendations provide a framework for mobilizing and guiding concrete action. It is feasible in the near term to align and strengthen climate services to enable society's efforts to adapt to a changing climate, at scale of the challenge. This will require aggressive action by key change agents, well-targeted investment, the commitment of national governments, and the knowledge and experience of the global climate services community of practice.

TABLE 2 Summary of recommendations

CHALLENGE		RECOMMENDATION	ENTRY POINTS
Decision-maker capacity and influence	1	Invest in the capacity of decision-makers in climate-sensitive sectors to use climate information effectively, identify their information needs, and strategically drive the co-production of climate services.	
	2	Promote, guide and invest in the development of formal institutional and policy arrangements that sustainably support climate-sensitive sectors to engage their National Meteorological Services in co-production.	GFCS, UNFCCC, NAP support programs
Misuse of climate change projections	3	Mainstream good practice for long-lead adaptation decision-making into key investment-related activities, including consideration of other time scales of information as appropriate.	UNFCCC, development and adaptation donors, CSP
	4	Develop and promote good practice standards, and correct problematic practice, for the provision of climate change projections for adaptation decision-making.	IPCC, CSP
National climate information usability gap	5	Fill observational data gaps through data rescue, data merging and strategic observing infrastructure investment, so that local data can be the basis for historical and future climate information products.	WMO, ENACTS initiative and its funders
	6	Align seasonal forecasting conventions used by NMSs and RCOFs to better meet the known needs of local decision-makers.	WMO, Regional Climate Centers
	7	Shift national meteorological data policy from treating observational data as a source of NMS revenue, to making it available as a public good and foundational part of national climate services.	Adaptation and development funders, WMO
Fragmented knowledge and expertise	8	Engage the global community of practice to consolidate existing knowledge into guidance and standards for the co-production, translation, communication, evaluation and governance of climate services.	CSP, WMO/GFCS
	9	Develop a global professional organization, and national to regional counterparts, to support an inclusive climate services community of practice to share knowledge, coordinate action, mobilize resources and influence supply of climate information.	CSP, existing national and regional networks
Inadequate investment	10	Mobilize, align and coordinate climate service investment to incentivize good practice, and build supply-side and demand-side capacity in a balanced and sustainable manner.	Climate service funders

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