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Advancing climate services in South Asia

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ABSTRACT

Many communities in South Asia are highly exposed and vulnerable to weather and climate hazards, and climate services play an important role in managing present and future climate risks. Here we take stock of ongoing climate service activities under the Asia Regional Resilience to a Changing Climate (ARRCC) Met Office Partnership programme. ARRCC aims to strengthen climate resilience in South Asia through co-producing weather and climate services, building institutional capacities, and enhancing coordination across the region and in focal countries: Afghanistan, Bangladesh, Nepal and Pakistan. We identify what is working well and challenges that remain in the provision and uptake of climate services, focusing on examples of applying seasonal forecasts, sea-level rise projections, and extreme rainfall information for hydropower decisions. We demonstrate the value of building equitable and sustainable partnerships, enhancing knowledge sharing, strengthening evaluation, and approaches that combine model information within a decision-centred framework. Based on experiences in ARRCC, we find that climate information alone is often insufficient to meet decision-maker needs, and discuss the role for new climate impact services that integrate climate information with knowledge and tools on climate impacts and vulnerabilities.

Practical Implications

Climate change over the 21st century could have profound and largely negative impacts in South Asia (Hijioka et al., 2014; Almazroui et al., 2020), limiting sustainable economic growth and efforts to reduce poverty (UNESCAP, 2020). Efforts to address increasing weather and climate risks, including weather and climate services, are therefore vitally important. Some countries in the region have relatively advanced weather and climate services compared to other countries (Krupnik et al., 2018), and support is needed within the region and from the international community to build capacities and share knowledge to meet the growing demand for weather and climate information.

The Asia Regional Resilience to a Changing Climate (ARRCC) Met Office Partnership programme, funded by the UK's Foreign, Commonwealth and Development Office (FCDO), is working with organisations in South Asia to strengthen the co-production and uptake of weather and climate services. Starting in September 2018, ARRCC is a four-year programme with both a regional and national focus in four countries: Afghanistan, Bangladesh, Nepal and Pakistan.

ARRCC is supporting activities across weather and climate timescales – our focus here is on climate. On seasonal timescales, the Strengthening Climate Information Partnerships South Asia (SCIPSA) project has provided funding and technical support to

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the South Asian Seasonal Climate Outlook Forum (SASCOF), which issues seasonal climate outlooks for the region. To support the aims of SASCOF, the project has built relationships and is jointly implementing new approaches with partners, including the Regional Climate Centre Pune at India Meteorological Department and the Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES). SCIPSA is also supporting the implementation of objective-based forecasting in line with World Meteorological Organisation guidance (WMO, 2020), strengthening regional and national level linkages, improving the usability of outputs provided to stakeholders, and embedding evaluation and learning.

The Climate Analysis for Risk Information and Services in South Asia (CARISSA) project under ARRCC aims to improve the uptake and use of climate change information in the region. An example is the development of new sea-level projections for South Asian locations, adapting methods from the 2018 marine UK Climate Projections, feeding into work with the Institute of Water Modelling (IWM) to develop coastal climate risk information in Bangladesh. CARISSA is also applying a climate information distillation approach (Jack et al., 2021) to co-develop information about extreme rainfall for hydropower stakeholders in Nepal, as well as improve understanding about climate change impacts on food security in Afghanistan and Nepal in collaboration with the World Food Programme (WFP).

Finally, ARRCC is advancing holistic socio-economic evaluation of weather and climate services in South Asia through the VALUE project. The project is working with, and training, climate service organisations (e.g. national meteorological and hydrological services - NMHSs) to evaluate their weather and climate services, in support of sustained funding and investment.

As the first phase of the ARRCC programme enters its final year, it is timely to reflect on challenges and opportunities presented to support further development of climate services in South Asia, including in a planned five-year second phase of ARRCC. While an increasing availability of observational and climate model data has helped organisations to meet some stakeholder needs, experience in ARRCC demonstrates that benefits can only be realised if investment in the science and modelling is coupled with investment in service provision. In particular, further investment is needed to develop skills and tools for translating and tailoring information for different user communities, as well as incentives for recipient communities to co-produce products and services (see also Krupnik et al. 2018). The international community has an important role to complement efforts led within the region, acknowledging the need for ethical co-development of climate services (Vincent et al., 2020) and ensuring future investments prioritise equitable partnerships in the scoping, implementation and evaluation of collaborative programmes.

Learning from ARRCC is relevant to other regions of the world, particularly low- and middle-income countries with comparable investment in weather and climate services. For example, the enhancement of SASCOF processes and outputs could be replicated in other regions. Embedding co-production principles into the development of seasonal forecast products, and efforts to strengthen regional to national linkages through support to national climate outlook forums, has achieved greater buy-in and visibility of forecast information amongst target communities.

We reflect that many decisions to address climate risks require information beyond climate data alone – e.g. setting regulations for climate-resilient hydropower in Nepal to mitigate risks from flooding and landslides. In these decision contexts, co-produced “climate impact services”, that integrate weather and climate information (including uncertainty information) with other non-climate and socio-economic data, can provide more relevant information to decision-makers. Advancing climate services in South Asia requires closer collaboration between disciplines, institutions, and potentially development of new institutions with multi-disciplinary expertise.

1. Introduction

Communities across South Asia are exposed to a range of weather and climate hazards. Climate change is affecting their frequency and severity (Hijioka et al., 2014). Recent climate model projections show temperature rises of several degrees by 2100 across South Asia, with a 6 °C increase in the Himalayas possible under a high greenhouse gas concentration scenario (Almazroui et al., 2020). Projections also show increasing annual precipitation, an intensification in monsoon rainfall, and increasing precipitation extremes over much of the region (Sanjay et al., 2017; Janes et al., 2019; Rai et al., 2019, Almazroui et al., 2020). Such changes will have widespread impacts on livelihoods, socio-economic sectors and ecosystems, with an estimated one billion people suffering from water stress by 2030 and more than 200 million people exposed to heat stress by 2040 (UNESCAP, 2020).

With a growing population increasing exposure, and high rates of poverty in the region, adaptation is required urgently to ensure sustainable and resilient development for vulnerable communities (Mall et al., 2019). Climate services have a vital role to play, enabling evidence-based decision-making to address climate-related risks (Srinivasan et al., 2011; Hewitt et al., 2012). However, there are often mismatches between available information and what is needed to support decision-making (Singh et al., 2018), varied capacities of individuals and organisations to use climate services (Dinku et al., 2014), limited understanding of their benefits (Bruno Soares et al., 2018), and broader ethical, governance and funding challenges (Bruno Soares and Buontempo, 2019).

Recent advances in climate science and the availability of climate information (past observations, seasonal and multi-year forecasts, and climate change projections) have underpinned the development of climate services (Gerlak et al., 2018; Hewitt et al., 2020). In addition, the demand for, and supply of, climate services in South Asia has evolved rapidly. Climate services are nascent in some countries while in other countries they are more advanced, providing opportunities for upscaling (Krupnik et al., 2018). For example, the Indian Ministry of Agriculture convenes regular weekly meetings of the Crop Weather Watch Group, an inter-ministerial mechanism to review weather and climate information from the India Meteorological Department to plan contingency actions to face extremes such as drought (Samra, 2004). And in Sri Lanka, the Department of Irrigation has been a proactive participant in the Monsoon Forum, being regularly held since 2009. Close interactions have helped implement a pilot project to estimate inflows in the Lunugamwehera reservoir in southern Sri Lanka, vital in deciding the management of the basin based on weather and climate information (WMO, 2018). To further strengthen climate services in South Asia, the WMO and RIMES have supported NMHSs to implement the Global Framework for Climate Services, establishing and strengthening engagement with policy and planning processes (Srinivasan et al., 2019). This work has particularly strengthened climate services on seasonal timescales through the regular South Asia Seasonal Climate Outlook Forum (SASCOF), including sector-oriented discussions and the initiation of National Climate Outlook Forums – see section 2.2.

Much of the development of climate services in South Asia has focused on the agricultural sector, as the main livelihood in the region (Ramakrishna, 2013; Tall et al., 2013) with progress focused on near-term forecasts (Singh et al., 2018). Agro-meteorological forecasts are produced in a number of countries to support households dependent on rain-fed livelihoods, including in India (Venkatesan et al., 2020), Bangladesh and Nepal (Sivakumar et al., 2014). The International Maize and Wheat Improvement Center (CIMMYT) has identified information needs of farmers in the Indo-Gangetic Plain in managing risks to wheat, maize and rice cropping systems, showing that information needs are growing due to climate change and that many decisions can be improved by using climate services (Tall et al., 2013).

Appropriate climate monitoring and modelling infrastructure, and human capacity to understand and translate data into actionable information, are essential for ensuring climate services provision and uptake (Srinivasan et al., 2019). However, sparse and poorly maintained observational networks exist in many South Asian countries, with studies recommending improvements to networks through increasing the number of automated weather stations, tide gauges and enhanced data management and dissemination activities (Krupnik et al., 2018; Tall et al., 2013).

To improve the management of climate-related risks, and enhance resilience of countries and communities in South Asia to climate variability and climate change, climate services are required across temporal and spatial scales. To help achieve this, the FCDO is partnering with the Met Office and the World Bank on the four-year ARRCC programme, aiming to enhance regional coordination and strengthen weather and climate services across South Asia and in four focus countries: Afghanistan, Bangladesh, Nepal and Pakistan. Beginning in September 2018, the ARRCC Met Office Partnership programme[2] (hereafter referred to simply as ARRCC) involves collaboration with organisations across South Asia and comprises work packages spanning timescales, recognising the need for impact-based early warnings to reduce risks from weather hazards, and longer time-scale seasonal and climate information to inform contingency planning and climate change adaptation decisions. Here we take stock of the ARRCC programme to critically assess progress in advancing climate services in South Asia, articulating gaps and opportunities for continued investment.

Section 2 provides further details of climate service activities in ARRCC. Section 3 discusses key lessons learned and remaining challenges to overcome. In Section 4 we consider the need to move beyond climate information alone within the development and delivery of climate services. Section 5 provides conclusions and key recommendations for advancing climate services in South Asia.

2. Co-developing climate services

2.1. ARRCC Met Office Partnership programme design and structure

A scoping study conducted in 2018 included desk-based assessments of past and ongoing activities, and interviews with experts and stakeholders from relevant organisations to identify needs, gaps and opportunities. Consultation with directors and senior staff at focal country NMHSs focused on understanding their strategic priorities. Engagement with humanitarian sector organisations highlighted needs regarding early warnings for weather and climate risks (e.g. flooding and heatwaves). These consultations, and conversations with many other stakeholder communities (e.g. development banks, FCDO country offices, WMO), shaped project ideas which were discussed with FCDO, partner organisations and a range of beneficiaries. Ideas evolved over several months of iteration into broader projects (work packages) containing multiple activities.

The ARRCC programme is structured around four principal work packages (Fig. 1). Work package 1 is training NMHSs to implement impact-based forecasting (IBF) on weather forecast timescales, supporting disaster risk reduction and decision-making to address weather risks (Harrowsmith et al., 2020). Since this paper is focused on climate services, we do not provide further details of this work package, though we consider the concept of impact-based forecasting on climate timescales in section 4. Work packages 2 and 3 focus on seasonal and long-term climate services respectively - detailed in sections 2.2 and 2.3. Across ARRCC there is a cross-cutting theme on institutional capacity building, knowledge exchange and regional collaboration, outlined in section 2.4. Work package 4, detailed in section 3.2 in relation to lessons learned, focuses on evaluating the socio-economic benefits of weather and climate services using case studies from work packages 1–3.

In addition to the ARRCC Met Office Partnership and the World Bank led component of ARRCC, a monitoring, evaluation and learning component is being conducted by Oxford Policy Management. Overall programme results in the ARRCC "Theory of Change" and log-frame provide details of programme targets, including impact, outcome, intermediate outcomes and outputs, with associated indicators to monitor progress. Progress is reported through an annual review process. Delivery partners (Met Office and World Bank) continuously utilise the monitoring tools to gather feedback from stakeholders on activities. For example, following delivery of training events participant surveys provide feedback on their usefulness and effectiveness, and for selected target organisations (e.g. NMHSs) an annual assessment considers how programme activities are supporting sustainable institutional capacity development. A mid-term review was conducted in 2021 (results not yet available), assessing programme deliverables and reporting, and using key informant interviews with 44 individuals from 20 beneficiary organisations. Learning papers and case studies are being developed, utilising similar consultative approaches, on topics including understanding capacity gaps in NMHSs, the role of regional forums in facilitating cooperation, and innovation under ARRCC.

2.2. Operational seasonal forecast information services

Climate services utilising seasonal forecasts require robust processes and reliable forecast data at suitable spatial scales and lead times to support decision-making (Fig. 2). In South Asia the starting point is SASCOF, a twice-yearly Regional Climate Outlook Forum (RCOF) where seasonal climate outlooks are prepared and disseminated for the region. Established in 2010, the SASCOF involves collaboration between NMHSs, Regional Climate Centre Pune and WMO Global Producing Centres, and provides a platform for interaction between scientists and users of climate services through the SASCOF Climate Services User Forum.

The SCIPSA project (ARRCC work package 2) has supported eight SASCOF events since September 2018, helping to improve technical processes for generating forecasts, strengthening regional and national level linkages, improving the usability of information provided to stakeholders, and embedding evaluation and learning through regular surveys - elements seen as critical to the success of RCOFs (Gerlak et al., 2020). SCIPSA is supporting the implementation of standardized objective procedures for seasonal climate outlook preparation. During SASCOF-14 (Nepal, April 2019) the forum was selected as one of four pilot RCOFs to demonstrate good practice in adopting the WMO "Guidance on Operational Practices for Objective Seasonal Forecasting" (WMO, 2020). Efforts are ongoing to further support the WMO pilot, including research evaluating the performance of seasonal forecast models (Stacey, 2021).

SCIPSA has facilitated enhancement to the Seasonal Climate Outlook Statement for use at national levels by NMHSs. Through gathering user requirements and seeking feedback on prototypes, an updated product[3] has been co-produced, improving the format, providing clearer messaging and including national-level information. In addition, in Bangladesh, Nepal and Pakistan, SCIPSA has supported planning and contributed scientific input to National Climate Outlook Forums (National Monsoon Forums), which provide a national platform for dialogue between NHMSs and stakeholders (WMO, 2018) following the SASCOF.

Support is also being provided to NMHSs to advance operational seasonal climate services for downstream users, such as agriculture stakeholders in national research institutions and government

[2] https://www.metoffice.gov.uk/services/government/international-development/arrcc.

[3] Available at https://rcc.imdpune.gov.in/Products.html - Regional Climate Centre Pune (RA II Region) products; select Enhanced SASCOF outlook for tailored prototype product.

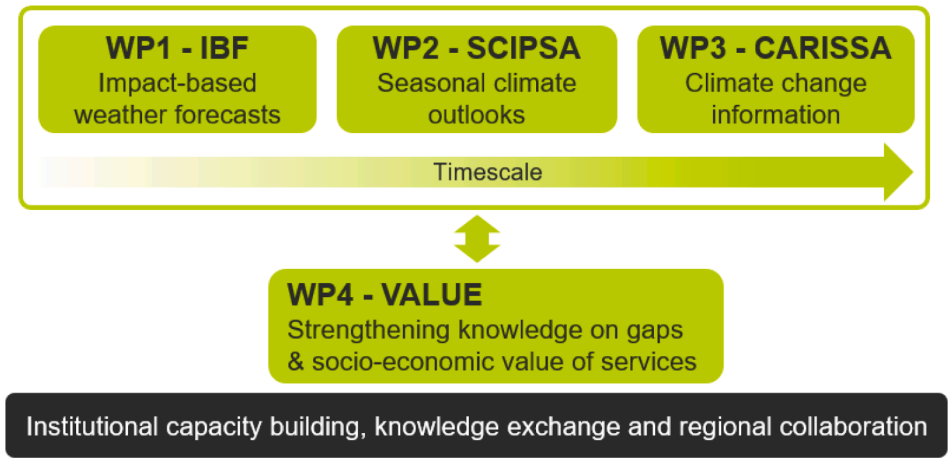

Fig. 1. ARRCC Met Office Partnership programme structure.

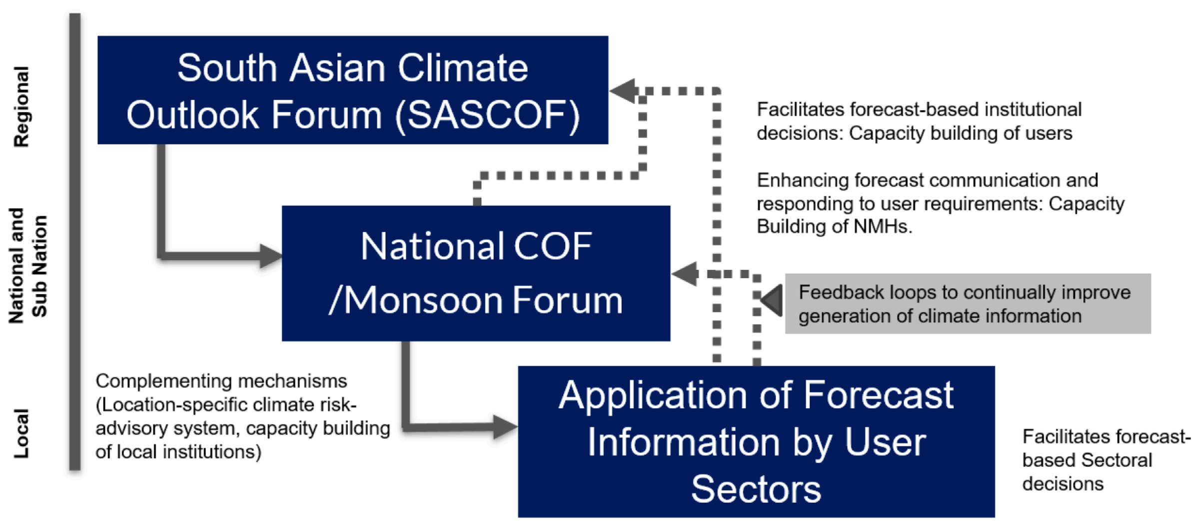

Fig. 2. Framework for climate services using seasonal forecasts in South Asia.

departments in Nepal and Bangladesh. Country-specific co-production workshops, held virtually in 2021, facilitated open dialogue between NMHSs and representatives from ministries and research councils – for example the Department of Agricultural Extension in Bangladesh, who have a key role in delivering climate services to farmers. These dialogues explored the need for seasonal information amongst decision-makers, levels of common understanding, and identified iterative approaches to enhancing uptake of seasonal climate information at the national level.

At the regional level, a two-day workshop in September 2019 following SASCOF-15 was held with seasonal forecasters, representatives from key sector organisations, and national government stakeholders. Participants engaged in interactive sessions to better understand decision-making contexts and methods for distilling and communicating complicated scientific information to enable effective decision-making. These interactions have enhanced dialogue and the implementation of co-developed prototype decision support systems.

In addition, together with the United Nations Economic and Social Commission for Asia (UNESCAP) an expert dialogue was convened during UNESCAP Disaster Resilience Week 2019. The dialogue reviewed existing regional cooperation for multi-hazard early warning systems across weather and seasonal timescales to respond to new challenges, trends and opportunities. It focused on developing a shared understanding among scientists, policy makers and practitioners (e.g. disaster management agencies, humanitarian organisations), leading to the establishment of a regional mechanism and learning platform for transboundary floods and droughts in South Asia. Through this mechanism, a regional workshop was held in December 2020 to improve awareness and capacities amongst forecasters, officials in local flood and drought forecasting, and disaster risk reduction agencies about available forecasting products and tools. In parallel, through a co-production process with regional stakeholders, UNESCAP have developed a methodology using the SASCOF consensus outlook to generate impact scenarios across a range of sectors (e.g. disaster risk reduction, agriculture and food security), supporting a new operational climate service for regional and national users in South Asia.

2.3. *Climate change information services*

On longer timescales, the CARISSA project (ARRCC work package 3) aims to improve the uptake and use of climate change information in South Asia. A regional consultation workshop[4] in January 2019 helped identify priority activities for CARISSA. The interactive workshop included providers, intermediaries and users of climate services, and

[4] Workshop report: https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/business/international/final_arrcc_carissa_regional_workshop_jan2019_report.pdf.

resulted in establishing five key themes to frame activities: 1) Regional coordination, cooperation and collaboration; 2) data access and sharing; 3) sector focused engagement, tools and information products; 4) support for national and regional climate projections; and 5) training and capacity building. To advance work under each of these themes, collaborations were established with key partners - the International Centre for Integrated Mountain Development (ICIMOD), Red Cross Climate Centre, WFP, and IWM in Bangladesh - to co-develop climate services with stakeholders in different applications. Here we highlight two examples. The project is also helping to build the capacity of climate service providers and users to analyse and apply climate change information (see section 2.4).

2.3.1. Coastal climate risk services

One focal area is sea-level rise and coastal risk information services. The work centres on new sea-level projections for tide-gauge locations across South Asia (Harrison et al., 2021), generated by adapting methods used in the United Kingdom Climate Projections 2018[5]. The projections are being embedded in new research and policy dialogues to advance adaptation planning in Bangladesh and Pakistan. Prior to ARRCC, there were no local sea-level projections available and planning assumptions in these countries relied on extrapolation of past sea-level rise trends from tide gauge records or global and ocean-wide estimates of sea-level rise (Harrison, 2020; Weeks and Harrison, 2020).

In both countries, the project team has engaged through focused meetings, training events and webinars with government and academic stakeholders involved in research and planning to address sea level rise (e.g. Bangladesh Water Development Board and the Pakistan Water Environment Forum). Two remotely delivered training workshops led by sea level experts at the Met Office were held in Bangladesh (November 2020) and Pakistan (June 2021), in partnership with the Bangladesh University of Engineering and Technology, the Pakistan Meteorological Department and ICIMOD. They were aimed at the NMHSs, research institutes, and technical officials in government planning agencies to help strengthen understanding of sea-level science and projections. In Pakistan, the engagement led to the formation of a new sea level unit at Pakistan Meteorological Department to align with work at the National Institute of Oceanography. Following each training event, science-policy webinars were organised to share knowledge across a broader practitioner and policy audience, including opening remarks from FCDO country offices and panel sessions with climate change adaptation experts[6].

In Bangladesh, a two-year project is being conducted by IWM under ARRCC to integrate the new projections with local data along the coastline, including modelling coastal impacts in the Bay of Bengal and delta region of Bangladesh. The project is designed to inform the implementation of national and local adaptation decisions, such as the Bangladesh Delta Plan 2100[7], through direct engagement with implementing agencies (e.g. Bangladesh Water Development Board).

2.3.2. Climate information distillation for the hydropower sector in Nepal

Hydropower is crucial to Nepal's energy security, generating 90% of power with further expansion planned (USAID, 2017). However, the sector is vulnerable to current and future climate risks. To co-produce climate information for hydropower stakeholders in Nepal, the CARISSA team developed and are implementing a Climate Information Distillation Framework (Fig. 3), building on previous work in Africa (Jack et al., 2021). The framework guides the process of co-producing climate information for a target audience. In practice work is iterative across the stages but the framework helps communicate the overall approach and plan tasks with collaborators.

Initial needs and vulnerabilities were identified (stage 1) through a series of conversations and a workshop in September 2019, hosted by ICIMOD. Consultation involved a range of stakeholders, including government departments (e.g. Department of Electricity Development) and private hydropower developers. This highlighted a gap in understanding how projected changes to extreme rainfall in Nepal would impact hydropower policy and decisions. It was agreed that new analysis was required to better quantify present and future risks (Stage 2). In implementing the technical stages of the framework (Stages 3 and 4), best practice in process-based evaluation of climate model simulations (Eyring et al., 2019) was adopted to identify, evaluate and combine suitable sources of information.

Work is ongoing under stages 5 and 6 of the framework to re-engage with key stakeholders. In collaboration with ICIMOD, the Nepal Department for Hydrology and Meteorology, and the Nepal Development Research Institute, the team has established an ongoing dialogue with key national stakeholders, particularly Nepal's Electricity Regulatory Commission. The dialogue, currently through a series of regular remote meetings, aims to further understand the decision context to inform tailored outputs that can support policy and planning at national and basin levels. It also provides the opportunity to discuss the benefits and limitations of climate data, helping manage expectations about the appropriate used of climate information. In response to the dialogue, a series of "explainers" have been produced (e.g. on evaluating climate models, and observations of rainfall) to help communicate findings and seek feedback to inform future work. In doing so, the team is navigating the intricacies of integrating climate data with non-climate data (e.g. river flow data) to distil and communicate actionable information (see section 4). Final outputs are in development and once available they will be evaluated with target stakeholders to assess their value to policy and decision making.

2.4. Building institutional capacity and regional collaboration

A central pillar of ARRCC is institutional capacity building of NMHSs and organisations providing and using climate services, contributing to two of four Global Framework for Climate Services capacity development areas[8]: human resource capacity and procedural capacity. Activities have been informed by training needs assessments and have been delivered jointly with partners.

In SCIPSA, training activities have leveraged the SASCOF and partnership with RIMES as a regional training centre. Training on objective dynamical model-based seasonal forecasting has been provided to NMHSs (February 2019 and February 2021), as well as a workshop on the challenges of distilling multi-model information (August 2020). Climate service training has also been provided to the Nepal and Bangladesh NMHSs and representatives from the agricultural sector (May and June 2021) to develop national seasonal outlook products that inform agrometeorological advisories, including guidance on methods for co-production and user engagement to improve dialogue between NMHSs and agricultural practitioners.

In CARISSA, ICIMOD led training workshops in October 2020 and June 2021, in collaboration with the Indian Institute of Tropical Meteorology and the Met Office, to strengthen capacities of NMHSs and organisations using regional climate projections[9]. They have enabled participants to download and analyse regional climate model data from

[5] https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/marine-projections.

[6] ARRCC webinar: Sea level rise and coastal climate risks in Bangladesh: https://www.youtube.com/watch?v=LqnNll5oltk.

[7] https://bangladeshembassy.nl/bangladesh-delta-plan-2100/.

[8] Annex to the Implementation Plan of the Global Framework for Climate Services – Capacity Development: https://gfcs.wmo.int/sites/default/files/Components/Capacity%20Development//GFCS-ANNEXES-CD-FINAL-14143_en.pdf.

[9] https://www.icimod.org/event/spatial-and-temporal-climate-change-analysis-using-cordex-regional-climate-models-over-south-asia/.

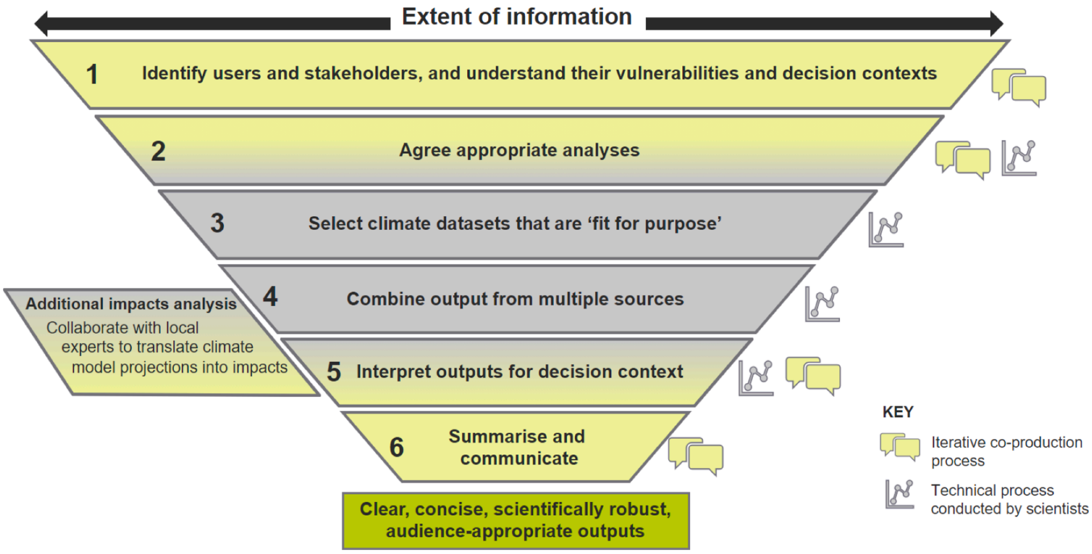

Fig. 3. CARISSA climate information distillation framework.

the CoOrdinated Regional Downscaling EXperiment (CORDEX) for analysis over South Asia. Capacity building activities have also included sea-level science training (see section 2.3.1), use of "Climate Grid" for generating gridded climate observations by Pakistan Meteorological Department, and introductions to climate science and climate information provided to WFP staff in Nepal and Afghanistan in December 2020.

Covid-19 travel restrictions have introduced challenges for training activities, especially for participants with limited access to appropriate IT and high-speed internet. Nevertheless, ARRCC has continued to deliver training remotely where possible, and in some instances, such as the sea-level training events, this has broadened participation achieving better gender balance and efficiencies in enabling more facilitators to deliver training.

A related area of focus has been on promoting mechanisms for knowledge sharing and access to climate change information. During a side event at the sixth International Conference on Climate Services (ICCS6), hosted by Indian Institute of Tropical Meteorology, participants from South Asia explored opportunities for co-developing a new regional knowledge forum on climate change science and services. Three activities have subsequently pursued: 1) Establishing an online community of practice on climate change science and services; 2) Incorporating climate change information into the SASCOF; and 3) Establishing a regular in-person regional forum on climate change in South Asia. Whilst advances have been made towards these aims, the Covid-19 pandemic has delayed progress. Crucially, these efforts must align with other initiatives, including the recent establishment of the South Asia Hydromet Forum[10] through the World Bank partnership under ARRCC, as well as national efforts to enable coordination and collaboration among stakeholders (e.g. national frameworks for climate services).

3. Challenges and lessons learned

3.1. Data, information and knowledge gaps

Through scoping and co-developing climate services in ARRCC, a number of challenges and lessons have emerged. Some challenges facing South Asia are similar to those in other regions (see Hewitt et al., 2020). For example, NMHSs have limited resources to develop climate services in addition to maintaining operational responsibilities, and while they nominally have a national mandate for providing climate information to government, the public and other organisations, they often lack capability and knowledge (e.g. for sea-level and future climate projections). A common practical challenge is managing large climate datasets which require substantial computational facilities and expertise to store and maintain. Expertise is also needed to process, analyse and communicate climate data. Activities in ARRCC are helping to address these challenges (see section 2.4), through tailored training and development of new tools, but sustained efforts are required beyond a single programme and further investment is needed.

Other challenges are unique to the South Asian context. The Himalayas and the Indian Ocean dominate the nature of weather and climate hazards that affect the region. Complex topography affects the reliability and availability of observations, constraining model forecasts and projections. Engaging with hydropower stakeholders, interested in basin-level flooding and landslide risks, demonstrates that sparse observational networks and substantial biases in models limit the extent to which climate information can reliably inform decision-making. Improved monitoring networks are essential to support the development of services across weather, seasonal and climate timescales, such as transboundary early warning systems.

One central challenge in South Asia is the lack of relevant and usable climate *risk* information for application in different contexts. For example, in August 2019 an expert dialogue jointly organized by UNESCAP, the Met Office and RIMES discussed "Scaling Up Regional Cooperation in Multi-Hazard Early Warning Systems in Asia and the Pacific", focusing on flood and drought hazards. The dialogue concluded that available multi-hazard and climate risk information was insufficient, recommending increased efforts to: i) translate seasonal outlooks into social and economic impact outlooks, ii) integrate forecast information with broader information on hazards, vulnerability, risk, and impacts on people, economies, and infrastructure to inform national policy planning, and (iii) enhance and develop new regional learning platforms for flood forecasting in transboundary river-basins. We further reflect on how to address these challenges in section 4.

Across South Asia there remains limited knowledge and understanding on how existing services are used amongst target users. ARRCC has helped generate new evidence in specific contexts – e.g. in the use of SASCOF outputs by seasonal forecasters at NMHS. Partners in ARRCC are beginning to gather further evidence (see section 3.2) which is essential to understand what is working well and what areas need improving.

[10] https://www.worldbank.org/en/events/2019/11/19/south-asia-hydromet-forum-ii.

Finally, the Covid-19 pandemic has affected stakeholder engagement and collaboration amongst partners, with a reliance on online tools. In some cases there have been opportunities - for example in broadening the reach of training events and webinars - but in other cases the lack of reliable internet and ability of people to work effectively away from an office environment has prevented progress. These impacts stress the importance of effective internet-based communication and collaboration, which will remain critical in the future development and delivery of climate services. Moreover, the shift in working practices provides an impetus for further innovation in climate services to adopt new technologies and reach new audiences (Hewitt and Stone, 2021).

3.2. Sustaining investment in climate services

Justifying investment in climate services requires understanding the range of potential benefits (Bruno Soares et al., 2018). However, knowledge is limited due to the complexity of climate services as an emerging field (Bruno Soares and Buontempo, 2019), the range of evaluation approaches used (Suckall and Bruno Soares, 2020a), and the multiplicity of benefits that can be realised and captured (WMO, 2015). Suckall and Bruno Soares (in review) take stock of existing attempts to evaluate weather and climate services in South Asia, showing discrepancy between their perceived value at the development stage compared to implementation, and highlighting that existing studies focus on economic benefits rather than holistic and comprehensive assessments of the range of benefits that can be realised.

Within ARRCC, the VALUE project led by the University of Leeds is evaluating existing and new climate services within the region to understand their value to end-users and beneficiaries. In collaboration with ICIMOD the project is implementing an evaluation of the agrometeorological services currently provided by the Pakistan Meteorological Department. Despite the range of services available in Pakistan through a range of mechanisms (websites, email, social media and in-person forums), little is known about their perceived benefits and use by farmers. Using household surveys and focus groups in the Punjab and Sindh regions, where cotton and wheat are the predominant crops, VALUE is investigating the current use of agrometeorological services to provide insights into the socio-economic benefits from the perspective of farmers.

Experiences in ARRCC demonstrate a need for increased and sustained national-level investment in NMHSs in the region, including underpinning climate information monitoring and modelling systems but also services and skills development, including training in evaluation methods (Suckall and Bruno Soares, 2020b). Holistic socio-economic evaluation studies are key to support NMHSs in the region to make the case for long-term investment. However, the investment landscape is often poorly coordinated across donors and national governments which can lead to confusion, duplication of effort and critical gaps being missed across programmes. NMHSs often feel overburdened and have difficulties balancing the range of donor funded initiatives with operational commitments. Investments must therefore support their wider strategic plans.

3.3. Value of partnerships

Effective and sustainable climate services depend on effective institutional partnerships, dialogue and collaboration (Srinivasan et al., 2019; Hewitt and Stone, 2021). These notions are at the heart of the ARRCC programme, acknowledging the value of building long-term relationships and working across disciplines, institutions, countries and cultures. Yet experiences in ARRCC also highlight the need for clarity about organisational mandates and roles for each partner in developing or delivering a climate service.

By design, ARRCC is working closely with partner organisations to ensure effective implementation and pathways for sustainability beyond the current programme at national and regional levels. Partners include NMHSs and scientific institutions (e.g. universities), regionally mandated organisations (ICIMOD, RIMES and Regional Climate Centre Pune), UN bodies (WMO, UNESCAP and WFP), humanitarian sector organisations (e.g. Red Cross Red Crescent Climate Centre), and development funders (e.g. World Bank). These partnerships have also been critical for buy-in and trust in the development of climate services. For example, the SASCOF is highly valued amongst stakeholders because of the strong partnership between organisations. In the past decade SASCOF has successfully engaged many stakeholders in the production and use of seasonal forecasts and, supported by ARRCC, national and regional partners are now working together to address new areas. The institutional capacity building approach in CARISSA, developed jointly by the Met Office and ICIMOD, also depends on strong partnerships and trust established with NMHSs and other relevant organisations (see section 2.4).

4. Moving beyond climate information

Though definitions differ, climate services broadly aim to provide climate information that supports decision-making to manage risks arising from climate variability and change (see Hewitt and Stone, 2021 and references therein). Yet, as discussed in the previous section, gaps remain in data, information and knowledge (Hov et al., 2017; Hewitt et al., 2020) and to effectively manage climate-related risks, decision-makers must understand the limitations of climate information (Nissan et al., 2019).

Gaps in scientific and technical capabilities underpinning climate services have been discussed extensively elsewhere (Brasseur and Gallardo, 2016; van den Hurk et al., 2018; Skelton et al., 2019; Hewitt et al., 2021) but even with improved underpinning capability there is still a need in many contexts for more interdisciplinary services that integrate climate with other physical and/or socio-economic information to better articulate climate impacts (Daron et al., 2015; Bruno Soares and Buontempo, 2019). Examples from ARRCC include the need to integrate seasonal forecasts with socio-economic and agricultural datasets to support agrometeorological advisories for addressing food insecurity (see section 2.2), and integrating present and future extreme rainfall information with hydrological and geophysical information to guide hydropower policy and planning (see section 2.3.2). While climate impacts science in these areas may be mature, in South Asia and elsewhere there is a lack of integration and translation of such information to meet decision-maker needs.

Extending climate services to provide information about the impact of climate variability and climate change on the key pain points of decision-makers, requires a class of more advanced "climate impact services". This is analogous to climate adaptation services, which translate climate information into policy-relevant indicators to support the design of adaptation strategies (Goosen et al., 2014).

To explore this further, we can learn from the recent development of impact-based forecasting (IBF) on near-term weather timescales. IBF translates forecasts from "what the weather will be into assessments of what the weather will do" (Harrowsmith et al., 2020) providing weather impacts information and warnings (e.g. likelihood of disruption to roads from high winds, or increased disease-risks due to flooding), informing specific actions to manage weather risks. In ARRCC Work Package 1, forecasters at South Asia NMHSs are being trained and equipped with tools to enhance their IBF capabilities.

IBF principles and approaches could be adapted to climate impact services. However, this requires overcoming challenges prevalent on climate timescales, including the availability of relevant and reliable historical data and knowledge on climate impacts. Also, in constructing information about future climate impacts using multi-decadal climate projections, researchers must also consider how societal contexts might change in the future, where anticipated impacts fall outside of the range of past experience (e.g. impacts from a 1 m rise in sea-level). Ascribing likelihood statements to potential impacts becomes more difficult and is highly dependent on assumptions.

Enhancing institutional capacity is key to advancing climate impact services. For regional and national climate service providers to meet the growing and complex demands of stakeholders, it has been argued that institutions should host centres with a diversity of staff including specialists in impacts, adaptation and vulnerability, with experts in areas such as economics and engineering (Brasseur and Gallardo, 2016). For many climate service institutions in South Asia, this may not be realistic in the short-term but strengthening partnerships between institutions can also promote interdisciplinarity and knowledge sharing. ARRCC is supporting this aim in the establishment of a regional forum for knowledge exchange on climate science and services (see section 2.4).

5. Conclusions

Climate services have an important role to help governments, industry and communities confront the challenges of climate variability and change. In South Asia, the maturity of climate services provision and uptake varies between countries but new investments and initiatives, including ARRCC, are helping to strengthen capabilities and advance climate services. Critical to the success of such programmes is establishing buy-in, shared goals and cooperation of partners at the regional and national level, recognising that each organisation has different mandates and priorities.

The ARRCC programme has strengthened existing partnerships and developed new partnerships with organisations at the regional and national level. For example, strengthening the SASCOF by supporting different organisations to participate and co-produce improved outputs for national stakeholders. Effort has also focused on institutional capacity building, targeted at NMHSs. Through embedding the principles of co-production in scoping, developing and evaluating climate services, activities have led to significant progress in areas such as coastal climate risk information, seasonal forecasts for the agriculture sector, and extreme rainfall information for hydropower stakeholders.

Challenges have been varied. The Covid-19 pandemic has affected ways of working, budgets and priorities, as well as personally affecting the lives of those involved in the programme. Yet the reliance on online communication and collaboration has prompted innovation, and in some cases increased participation in events. Another challenge in develop sector-specific climate services is the recognition that weather and climate information alone is often insufficient. There is a need for improved integration between disciplines and tools for risk-based information to better meet decision-maker needs, with a potential role for new climate impact services.

International investments in climate services development in South Asia, including ARRCC, can create many benefits and work is ongoing to quantify and communicate these benefits. However, funders and implementing organisations must remain sensitive to ethical challenges in co-producing climate services, particularly regarding potential power imbalances between institutions in the global north and south (Vincent et al., 2020). Future projects and programmes must prioritise equitable partnerships in the scoping, implementation and evaluation phases.

CRediT authorship contribution statement

J. Daron: Conceptualization, Writing – original draft. **M. Bruno Soares:** Conceptualization, Writing – original draft. **T. Janes:** Conceptualization, Writing – original draft. **F. Colledge:** Conceptualization, Writing – original draft. **G. Srinivasan:** Writing – original draft, Visualization. **A. Agarwal:** Writing – original draft. **C. Hewitt:** Writing – original draft. **K. Richardson:** Writing – original draft, Visualization. **S. Nepal:** Writing – original draft. **M. Singh Shrestha:** Writing – original draft. **G. Rasul:** Writing – original draft. **N Suckall:** Writing – original draft. **B. Harrison:** Writing – review & editing. **Rosie Oakes:** Writing – review & editing. **D. Corbelli:** Writing – original draft, Project administration.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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