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Examining the role of user engagement in the regional climate outlook forums: implications for co-production of climate services

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Examining the Role of User Engagement in the Regional Climate Outlook Forums: Implications for Co-production of Climate Services

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Contents

Abstract

The concept of co-production between 'producers' and 'users' of climate information has gained traction in recent years. However, questions remain about how co-production should be undertaken in practice in order to produce usable climate services. This article examines the role of user engagement in Regional Climate Outlook Forums (RCOFs) over the last 20 years, situating user involvement in relation to the multiple goals of the RCOFs, in order to draw out lessons for co-production of climate services more broadly. Results show that approaches to user engagement in the RCOFs have spanned a wide spectrum globally due to divergent stakeholder perceptions with regard to the importance of user engagement in relation to other goals of the RCOFs, as well as differences in institutional landscapes of 'users' and 'producers' across regions. As such, there is no 'best' way to approach co-production; rather, this article concludes that there is a need to: 1) generate refined understandings of regional users and their decision-making contexts, 2) acknowledge and clearly articulate the multiple goals and benefits of RCOFs, as well as roles and responsibilities, within a multi-level chain of climate services delivery, and 3) embrace more fluid and nuanced interpretations of co-production that are not necessarily limited to interactions between 'producers' and 'users.' These steps can lead to more deliberate and contextualized approaches to involving users, along with more reflexivity about when, where, why, and how – and perhaps most importantly whether – co-production should be undertaken. Such considerations will benefit broader efforts to develop usable climate services.

Key words: user engagement; co-production; climate services; seasonal climate forecasts; adaptation

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1. Introduction

Over the last decade, the concept of climate services has gained increasing popularity. While there is no single definition of climate services (Brasseur & Gallardo, 2016), the primary drive behind climate services reflects a desire to ensure that new developments in climate science and prediction, as well as existing data and information, are effectively translated into societal benefit through improved decision-making and action. This can include minimizing negative impacts or capitalizing on opportunities created by weather and climate at a variety of temporal and geographic scales (WMO, 2011).
The increasing interest in climate services is indicative of broader efforts to rework science-society relations in order to make climate science more responsive to decision-making contexts, as well as accountable to decision-makers and the public, who are the intended beneficiaries. The challenge of linking climate science and societal applications was acknowledged early on (Glantz, 1977), but was more fully realized through early attempts to practically apply seasonal climate forecasts in the late 1990s, which illustrated a range of barriers to the practical use of such information (Harrison et al., 2007; Murphy et al., 2001; Vogel & O Brien, 2006).

To improve the uptake of science within societal decision-making, it has been proposed that there is a greater need for collaboration and interaction between 'producers' and 'users'[1] of scientific knowledge, a process that has been referred to as "co-production of knowledge" (Mitchell, 2006). Co-production of knowledge between producers and users is widely considered imperative to deriving value from climate information and services (Murphy et al., 2001) and has become a widespread approach in recent years, particularly within climate change research (Bremer & Meisch, 2017). The basic premise of increasing interaction between producers and users to co-produce knowledge has been around for several decades in the area of climate information (see, for example, NOAA, 1998; WMO, 1997). However, there are few empirical studies of how co-production takes place, how these processes are institutionalized and sustained, and how this relates more broadly to the uptake and use of climate science for societal applications (see Bremer et al., 2017; Lövbrand, 2011; Nightingale, 2015; Tschakert et al., 2016; van der Hel, 2016 for exceptions).

In this paper, we seek to draw key lessons from two decades of user engagement within Regional Climate Outlook Forums (RCOFs). RCOFs are meetings that bring together scientific experts and stakeholders with the aim of producing regional-scale climate information products (generally seasonal climate forecasts) that are relevant for societal decision-making (WMO, 2016). RCOFs represent some of the earliest attempts to develop

[1] It is recognized here that the terms 'producers' and 'users' are too general to adequately capture the range of actors that are involved in co-production efforts, and are even counter to the notion of co-production in which all participants are considered knowledgeable partners engaged in joint efforts to produce new knowledge. Furthermore, the language of 'users' and 'producers' further reinforces power dynamics between actors because it implicitly values the knowledge of some actors over others and entrenches linear delivery of information (Daly, 2016). However, for simplicity and because the 'user' / 'producer' language is prevalent in the climate services literature, we will use the terms without quotations for ease of reading in the remainder of the article, while recognizing their problematic nature.

formal mechanisms for sustained interaction between producers and users of seasonal climate forecasts and are now conducted in nearly 20 regions globally. RCOFs, therefore, provide a valuable opportunity to learn and provide broader insights for the field, which is still assessing how best to integrate co-production of knowledge within the design and development of climate services.

To do so, we draw on document analysis, interviews with key informants, and participation in a global review of RCOFs. We situate findings about user engagement within an analysis of the historical evolution of the RCOFs, including their goals, institutional structures, and practices. In Section 2, we discuss the history of the RCOFs, including their establishment, expansion, and role as part of the broader climate services infrastructure of the World Meteorological Organization (WMO). In the third section, we describe the methods used to conduct this analysis. In Section 4, we present the results of the research, responding to the questions of: 1) what are the goals of the RCOFs and 2) how are users currently engaged in the RCOFs? We then discuss perceptions of persistent challenges faced within the RCOFs and implications of these findings for future co-production of climate services.

2. The Establishment and Expansion of Regional Climate Outlook Forums

The 1982/83 El Niño event produced significant and unexpected impacts on lives, well-being, and economies around the world. Following this event, large investments were made to develop seasonal to inter-annual climate predictions that could help societies to better prepare in the future (McPhaden et al., 1998). While there were high expectations about the potential for these forecasts to improve decision-making and to mitigate the impacts of climate variability, it was also recognized that, in order to achieve this, there was a need to connect these forecasts with potential users.

The first RCOFs were conceptualized and initiated by U.S. National Oceanographic and Atmospheric Administration's Office of Global Programs (NOAA-OGP) in the late 1990s (NOAA, 1998) as a means of disseminating and communicating seasonal forecasts to users, as well as exploring their potential applications (Buizer, Jacobs, & Cash, 2010). These initial RCOFs were backed by WMO (Buizer et al., 2010) and organized and implemented in partnership with a range of other organizations, including the U.S. Agency for International Development (USAID), the International Research Institute for Climate and Society (IRI), the World Bank, the U.K. Met Office, the European Commission, and numerous international and national weather and climate prediction centers around the world (NOAA, 1998).

The first RCOF was held in Southern Africa in September 1997 (Basher et al., 2000). Following this, the RCOFs expanded rapidly (see Figure 1 for a timeline of the establishment of RCOFs). By February of 1998, additional RCOF pilots were held throughout Africa, as well as in the Pacific, South America, Central America, the Caribbean, and Southeast Asia (NOAA, 1998). RCOFs are now held on a regular basis – generally 1 – 2 times per year – in nearly every region globally (see Figure 2), with some countries participating in multiple RCOF events. While most RCOFs hold physical, face-

to-face meetings, several RCOFs utilize video conferencing or online forums to facilitate virtual meetings. As of writing, there are 19 RCOFs in operation, with one additional RCOF to be established for the Polar region in 2018 (WMO, 2017).

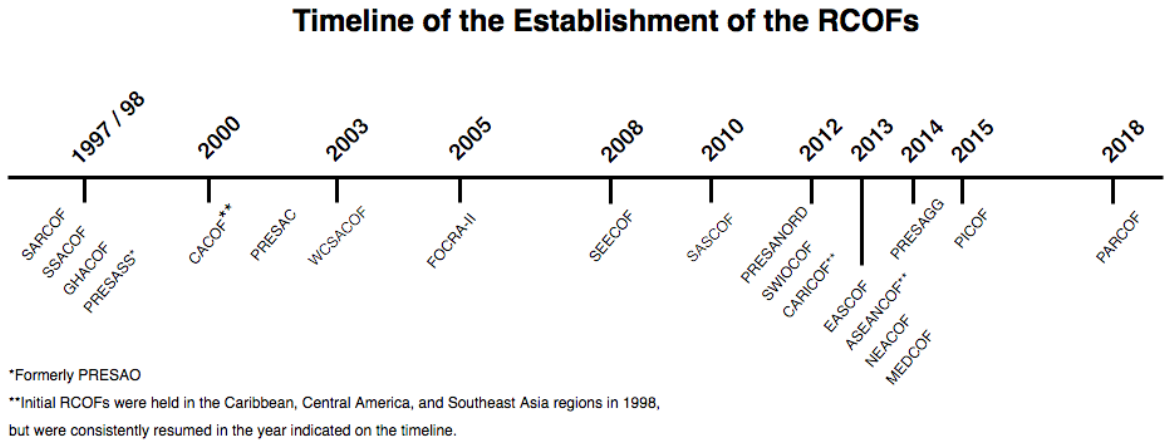

Figure 1: Timeline of the Establishment of RCOFs Globally
(Sources: NOAA, 1997; WMO, 2016; WMO, 2009; WMO Website: https://public.wmo.int/en/our-mandate/climate/regional-climate-outlook-products, accessed 15 November 2017)

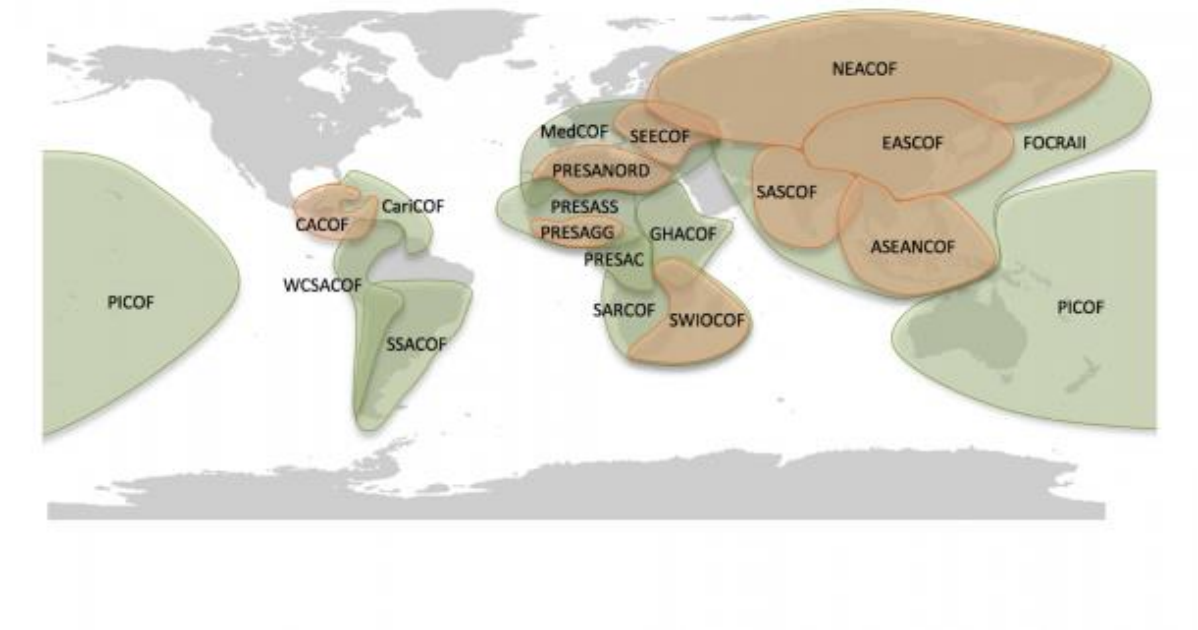

Figure 2: Map of Geographical Coverage of the RCOFs
(Source: WMO Website: https://public.wmo.int/en/our-mandate/climate/regional-climate-outlook-products, accessed 15 November 2017)

As RCOFs have expanded, each as evolved independently to fit the regional context, including adapting to existing institutions, geo-political relations, and modalities of cooperation in each location (See Table 1). However, RCOFs have also become progressively more integrated within WMO's climate services infrastructure, which has three tiers: global, regional, and national (Brasseur & Gallardo, 2016; Martínez Güingla, 2011). Within this system, RCOFs serve as a platform to facilitate linkages between national meteorological and hydrological services (NMHS) (national level) and WMO Global Producing Centers (GPCs) for Long-range Forecasting (global level) (WMO, 2003). Increasingly, RCOFs are coordinated by Regional Climate Centers (RCCs)[2], which are the primary regional institutional mechanism for climate services delivery under WMO. RCOFs are also considered important regional components of the operational climate services information system and user interface of the Global Framework for Climate Services (GFCS).

[2] RCCs can either be a single organization, or alternatively formed through a network (RCC Network) in which multiple organizations jointly fulfill the requirements and mandates of an RCC. A key function of the RCCs is to improve the availability of relevant regional data, information, and predictions (WMO, 2003), including the generation of a 'consensus' statement for regional or sub-regional seasonal climate forecasts (WMO, 2009a). The concept of WMO RCCs arose in the late 1990's, at the same time that RCOFs were first being implemented, but it was not until more than a decade later (2009) that the first RCCs were designated (Martínez Güingla, 2011) and most RCCs have received official approval by WMO only in the last few years.

WMO REGION	OUTLOOK FORUM	GEOGRAPHIC COVERAGE	TYPE OF COORDINATING ORGANIZATION(S)
Region I: Africa	GHACOF	Greater Horn of Africa	WMO RCC
	PRESASS	Sahelian Region	WMO RCC, Regional Inter-governmental Body
	PRESAC	Central Africa	WMO RCC, Regional Inter-governmental Body
	PRESAGG	Gulf of Guinea Countries	WMO RCC, Regional Inter-governmental Body
	PRESANORD	North Africa	NMHS, WMO RCC Network, WMO RCC
	SWIOCOF	SW Indian Ocean & Coast	WMO RCC, WMO GPC
	SARCOF	Southern Africa	Regional Inter-governmental Body, Proposed WMO RCC
Region II: Asia	EASCOF	East Asia	WMO RCC, WMO GPC
	FOCRA – II	Asia	WMO RCC, WMO GPC
	SASCOF	South Asia	WMO RCC
Region III: South America	SSACOF	Southeast South America	NMHS, WMO RCC Network
	WCSACOF	West Coast of South America	WMO RCC
Region IV: N. & Central America / Caribbean	CACOF	Central America	Regional Inter-governmental Body
	CARICOF	Caribbean Island Countries	WMO RCC
Region V: Southwest Pacific	ASEANCOF	Southeast Asia	NMHS, Proposed WMO RCC Network
	PICOF	Pacific Island Countries	NMHS, Regional Inter-governmental Body, Proposed WMO RCC Network, WMO GPC
Region IV: Europe	MEDCOF	Mediterranean Countries	NMHS, WMO RCC Networks
	NEACOF	N. Asia & N. Europe	WMO RCC
	SEECOF	Southeast Europe	NMHS, Regional Research Center
Multi-regional	PARCOF	Arctic Council Member States	NMHS, Proposed WMO RCC

Table 1: Global Overview of Institutional Landscape and Coordination of RCOFs

3. Methods

In this study, we examined the role of user engagement within the RCOFs over the last 20 years, to draw lessons that may inform co-production of climate services in the future. We did so by examining broader goals, practices, and components of the RCOFs, as well

as approaches to user engagement, and implications of these for efforts to co-produce climate services.

To begin, we conducted a review of academic publications, gray literature, and technical documents discussing the history and operations of the RCOFs. Second, we conducted both semi-structured and non-structured interviews with key informants who were involved in the establishment, implementation, and / or coordination of RCOFs at the global or regional scale (or both). Third, we participated in and observed the 2017 Global Review of the RCOFs, a three-day meeting organized by the WMO to evaluate the current status and practices of the RCOFs across all regions held in Guayaquil, Ecuador from 5 - 7 September 2017 (http://www.wmo.int/pages/prog/wcp/wcasp/meetings/workshop_rcofs.php).

Semi-structured interviews were conducted in person or via phone using a snowball sampling methodology, whereby the sampling frame was generated by interviewing several key individuals who are currently actively involved in RCOFs at the global scale. We then solicited recommendations for additional individuals to be included in the sample frame. We conducted a total of 15 interviews between January - August 2017, all of which were audio recorded and transcribed. An additional 10 non-structured interviews were conducted through convenience sampling (e.g. at conferences, meetings). Unstructured interviews were recorded through hand-written notes that were then digitized.

This sampling methodology enabled the inclusion of perspectives from a range of individuals across: 1) institutional scales, 2) types of organizations, and 3) geographical locations / regions. Interviews were conducted with individuals who had direct involvement across all RCOFs, with the exception of those held in Sudano-Sahelian, Central Africa, and Gulf of Guinea regions.[3] Participation in the Global RCOF Review Meeting by the lead author further enabled data collection across all 19 active RCOFs, as well as 1 RCOF that will be established in 2018. All interviews were analyzed using NVivo qualitative analysis software to identify emergent themes related to the goals, practices, components, and user engagement in the RCOFs.

4. Results

4.1 What are the goals of the RCOFs?

[3] Previously, there was one primary RCOF for the West Africa region (i.e. PRESAO), which covered portions of the current PRESASS, PRESAC, and PRESAGG RCOFs. Therefore, while interviews did not include respondents directly involved in these more recently formed sub-regional forums, several respondents had direct involvement in the PRESAO pre-cursor. Further, all of these RCOFs are currently coordinated by the African Center of Meteorological Application for Development (ACMAD), as was the PRESAO pre-cursor.

At the outset, the RCOFs were seen primarily as venues for the production of regional seasonal climate forecasts and for representatives from climate-sensitive sectors to discuss potential applications of climate information (NOAA, 1998). More recently, WMO has stated that RCOFs involve “delivering consensus-based, user-relevant climate outlook products in real time through regional cooperation and partnership” (WMO, 2009b). WMO further emphasizes several specific goals, including 1) production of an operational seasonal forecast at the regional scale, 2) capacity building, and 3) engagement with users of the forecast. Interviews with key informants largely reflected the goals discussed in the literature, with the exception of scientific consensus, which was highlighted an important feature among many interviewees, but was less frequently discussed in the literature.

Based on both the analysis of academic publications, gray literature, and technical documents, as well as interviews, it is possible to construct an overview of the goals of the RCOFs, as well as how these relate to each other. There are potentially a number of other objectives that the RCOFs may fulfil – for example, Guido et al. (2014) discuss other goals such as the quality of forecasts, improved communication, better policies, and enhanced livelihoods. However, we consider these more specific goals to fall under and / or to support the overarching goal categories of: 1) scientific consensus, 2) stakeholder engagement, 3) capacity building and networking, 4) production of usable regional climate outlooks on an operational basis, and 5) improved climate risk management and adaptation (See Figure 3).

It is clear that there are differences in the relative importance placed on each of these goals among interviewees, representing varying perspectives among individuals from different organizations and institutional scales, as well as across regions. Understanding these differences helps to contextualize how user engagement has (or has not) been taken up within RCOFs, and why. In the remainder of this section, we will discuss in further detail how each of these goals were variously interpreted by interviewees, as well how these goals relate to each other.

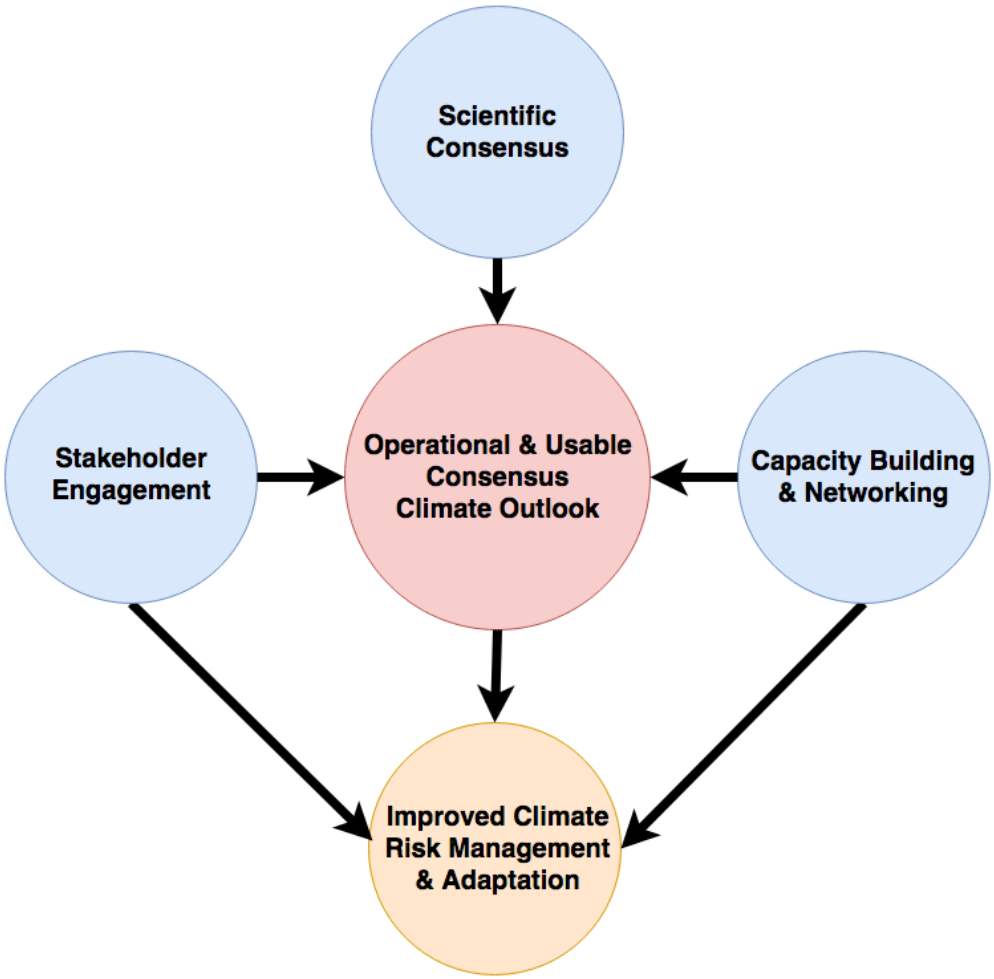

Figure 3: Goals of the RCOFs
(Goals are based stated goals of the RCOFs within literature and technical documents, as well as the perceived goals as expressed by interviewees involved in the establishment, coordination, or implementation of the RCOFs. Arrows indicate how various sub-goals support or contribute to end-goal of improved climate risk management and adaptation.)

Operational and Usable Climate Outlook

Unsurprisingly, many interviewees saw the production of an operational regional seasonal climate forecast, or 'climate outlook' [4], as being at the heart of the RCOFs activities and

[4] The product generated through the RCOFs is often referred to as a seasonal or climate 'outlook' rather than a forecast. In this sense, outlooks can best be understood as an integrated assessment of multiple seasonal forecasts. The outlook includes a range of information and analysis that may be important or relevant to potential users for understanding future climate conditions; however, the primary component is usually a probabilistic seasonal climate forecast for precipitation and / or temperature for the region. Therefore, we use the terms 'seasonal climate forecast' and 'seasonal' or 'climate outlook' interchangeably.

a key objective in and of itself [Int. 1, 11, 14, 18, see also WMO, 2017]. However, most interviewees recognized that it was not enough to produce just any seasonal forecast. Rather, the forecast, as well as associated products and services, must also be considered sufficiently credible [Int. 1, 11, 14, 17], legitimate [Int. 16, 17 18], and salient [Int. 1, 14, 15, 18] – or in other words, 'usable' (see Cash et al., 2003) – to effectively inform decision-making. In this way, the goals of capacity building and networking, stakeholder engagement, and scientific consensus were considered by many interviewees to be antecedent goals, that contribute to the production of usable, operational climate outlooks. However, not all interviewees agreed that the production of the regional climate forecast or outlook is the primary objective of the RCOFs, as will be discussed in the remainder of this section.

Capacity Building and Networking

RCOFs are also seen as key platforms for building regional and national climate prediction capacities and for facilitating knowledge exchange. This was seen as particularly important amongst the scientific community itself. According to one interviewee:

> [The RCOF's] main purpose is to bring climate scientists or climate people from the met services around the region together, to share experiences and learn from each other. That is the primary role, I think. So, it is an educational function, it is a training function, it is also a networking opportunity. The lesser important part of the RCOF, in my opinion, is actually doing the outlook. [Int. 13]

Similarly, another key informant indicated that, the while the forecasts were an essential component, the "most important part is getting them [meteorologists and climate scientists] connected, being networked" [Int. 16].

The capacity building component of the RCOFs is also seen as a means of leveling out disparities among NMHS within the region, to ensure that all countries have the basic capacities necessary to be able to produce their own national-scale seasonal forecast [Int. 16]. Further, networking was seen as enhancing the scientific credibility of the forecast products produced in the RCOFs through sharing of new methodologies and the state of the art. Ideally, capacity building is intended to improve the scientific rigor forecasts, which can help to improve the perceived credibility among scientists, as well as potential users.

Less frequently, capacity building activities have extended beyond improving scientific or technical abilities of the producers of the forecasts to address other skills. For instance, this has included efforts to encourage scientists to be more aware of and sensitive to the problems faced by potential forecast users, as well as to enhance the ability of various stakeholders to accurately understand and interpret climate information to effectively inform decision-making [Int. 14, 18].

User Engagement

User engagement is also seen as a critical goal of the RCOFs. This ranged from simply building awareness of available climate information [Int. 2, 14] to ensuring that potential users understand the limitations of scientific information to interpret it 'properly' [Int. 2, 14, 13, 16, 18]. Building long-term relationships and pathways for sustainable communication was seen as a key reason for engaging potential users in the RCOFs. This not only allows scientists to become aware of the needs of potential users, but also enables provision of feedback about whether current products are meeting their needs [Int. 2, 18]. Including users within the RCOF process was also considered a means of jointly exploring and developing new approaches to seasonal climate forecast applications [Int. 17]. The involvement of users within the forums was considered a means of enhancing the practical use of the information [Int. 14]. Just as importantly, however, engagement with users was seen as building mutual trust among all participants [Participant at the Global RCOF Review Meeting].

Scientific Consensus

While generally not overtly acknowledged within existing literature or technical documents (see Dilley, 2000; Hansen, Baethgen, Osgood, Ceccato, & Ngugi, 2007; Orlove & Tosteson, 1999 for exceptions), the RCOFs were perceived by interviewees to also be a crucial mechanism for producing an authoritative regional climate forecast. This is achieved through the development of a consensus-based forecast that integrates the knowledge and expertise of meteorologists and climate scientists in the region and beyond. This is why the product of the RCOF is generally referred to as the consensus outlook. The consensus forecasting approach emerged to achieve two objectives: 1) to ensure the credibility of the information produced and 2) to build the legitimacy of both the process and the products.

The credibility of seasonal climate forecasts can be interpreted differently by various RCOF stakeholders. Emphasis is often placed on improving technical measures of the credibility of the forecast, often referred to as the 'forecast quality.'[5] Considerable attention has been devoted to the verification of forecasts and many RCOFs calculate metrics such as hit-rates or skill-scores for their forecasts [Int. 10, 11]. RCOFs are intended to be a means of improving the technical quality of the forecast. However, how quality is assessed varies considerably from region to region and there are questions about whether RCOFs have actually contributed to improved quality of forecasts in some locations (Mason & Chidzambwa, 2009).

[5] In the field of climate forecasting, the concept of 'forecast quality' is frequently used. While there is no single, agreed upon measure for assessing the quality of forecasts, forecast quality generally refers to standardized, quantitative measures that can evaluate different aspects to determine how "good" a forecast is, in ways that are meaningful to climate scientists (Hill & Mjelde, 2002; Mjelde, Peel, Sonka, & Lamb, 1993). While the notion of forecast quality may be particularly important to forecasters, it can often have little meaning to non-scientists who have different ways of assessing the credibility of information. Therefore, we use the broader term of credibility here, which is relevant to scientists and non-scientists, rather than the narrower concept of forecast quality.

Respondents also emphasized other dimensions of credibility that are addressed through the consensus process of the RCOFs. For example, many interviewees noted the importance of leveraging all reliable information – to improve scientific credibility, as well as avoid confusion and mistrust among users who may be confronted with conflicting information sources. As recalled by one interviewee:

> It became pretty obvious, pretty quickly, that there were a few groups that were making forecasts in the country and in the region, and obviously they weren't all agreeing. And so, there was this developing confusion and concern about, you know, 'Whose forecast should we listen to? What's the authoritative forecast?' [Int. 10]

Thus, the consensus process was essentially a process to "set up a simple ensemble, which is really one of the earliest straightforward techniques of producing an ensemble, by using as many reasonable forecasts as you could" [Int. 8]. Developing a consensus was, in fact, seen by many interviewees as the most important motivation for the establishment of the RCOFs [Int. 5, 8, 10, 11, 15, 17, 18].

The consensus process is also seen as important for enhancing the legitimacy of the RCOF process, as well as the forecast products themselves [Int. 8, 10, 16, 17]. In the earliest days of seasonal climate forecasting, it was primarily universities or research institutions that were producing seasonal climate forecasts. Many NMHS felt that this could undermine their mandate as the authoritative producer of weather and climate information in their countries. Furthermore, many NMHS were not keen on having other organizations, whether from within or external to the region, producing forecasts for their country, As summed up by one respondent: "The most important thing that had to be addressed upfront was the national buy-in…If we [climate scientists] were going to produce anything, the individual countries had to be happy with it, and so that was very much an overriding consideration of the consensus-building, at least initially" [Int. 10]. Furthermore, it was recognized that "the Met Services like to have their own autonomy and they were not that keen on Scripps [Institute of Oceanography] or [the U.K.] Met Office or whoever sending the forecasts" [Int. 8]. The consensus process provides a means for all countries to be directly involved in its production, thereby increasing the legitimacy of the RCOFs.

Climate Risk Management & Adaptation to Climate Change

Implicit within much of the discussion of RCOFs is the assumed end-goal of improving climate risk management and adaptation. Aldrian et al. (2010) note that the RCOFs were formed with the assumption that climate information, including seasonal climate forecasts, should provide "substantial benefit to many parts of the world in adapting to and mitigating the impacts of climate variability and change" (p. 376). RCOFs were first created out of a desire to manage the impacts of seasonal to inter-annual climate variability by "emphasizing the importance of understanding climate and how you can deal with climate risk" [Int. 13]. Climate risk management approaches within the RCOFs are generally

organized sectorally and involve assessment of potential sectoral risks based on the forecast information in order to enable pre-emptive planning, decision-making, and action to mitigate or prepare for adverse impacts, or else take advantage of climate-related opportunities [Int. 14, 15].

WMO has stated that the RCOF concept also has "the potential to be extended to develop our capacity to adapt to climate change" (WMO, 2009a). While inclusion of information beyond seasonal to inter-annual time scales has taken place in some regions [Int. 11] and is planned in future RCOFs in other regions [Int. 16], it is acknowledged that, to date, there has been little discussion of long-term climate information (e.g. decadal or multi-decadal projections) in most RCOFs [Int. 1, 18]. Nonetheless, RCOFs were seen by many respondents as building a foundation to enable longer-term adaptation to climate change by providing a platform for stakeholders across disciplines to discuss climate issues on a regular basis, thereby creating greater awareness of climate-related issues and vulnerabilities more generally [Int. 1, 17]. This was seen as part of a "slow process of gradually understanding and being able to adapt or using information in a risk assessment and adaptation framework" [Int. 13].

4.2 How Are Users Engaged in RCOFs?

Engagement with potential users was an early rationale for RCOFs (Basher, Clark, Dilley, & Harrison, 2000; Buizer et al., 2010; NOAA, 1998; Orlove & Tosteson, 2002) and has gained importance as the RCOFs have increasingly become a central component of the user interface platform for the GFCS. However, as discussed in Section 4.1, not all stakeholders consider user involvement to be an essential activity. Consequently, user engagement has been taken up in different ways across the RCOFs. We find that there are three general ways in which the role of users has been conceptualized within RCOFs to date (See Figure 4).

In the first model, the role of users is primarily as recipients of the forecast. This reflects 'linear' approaches that are geared toward enhancing the dissemination of the forecast, educating potential users on interpretation of the forecast, and identifying applications of the forecast [Int. 11]. The second model frames users as conduits for delivering feedback about the forecast and as "adding value" through interpretation for sectoral applications or integration within sectoral impact models [Int. 11, 9]. Finally, within the third model, producers and users form active partnerships in which expressed needs of users inform or drive the development of new climate science, products, and tools [Int. 2, 16]. In some cases, this can also involve joint production and delivery of climate services products (e.g. risk analysis, tailored advisories).

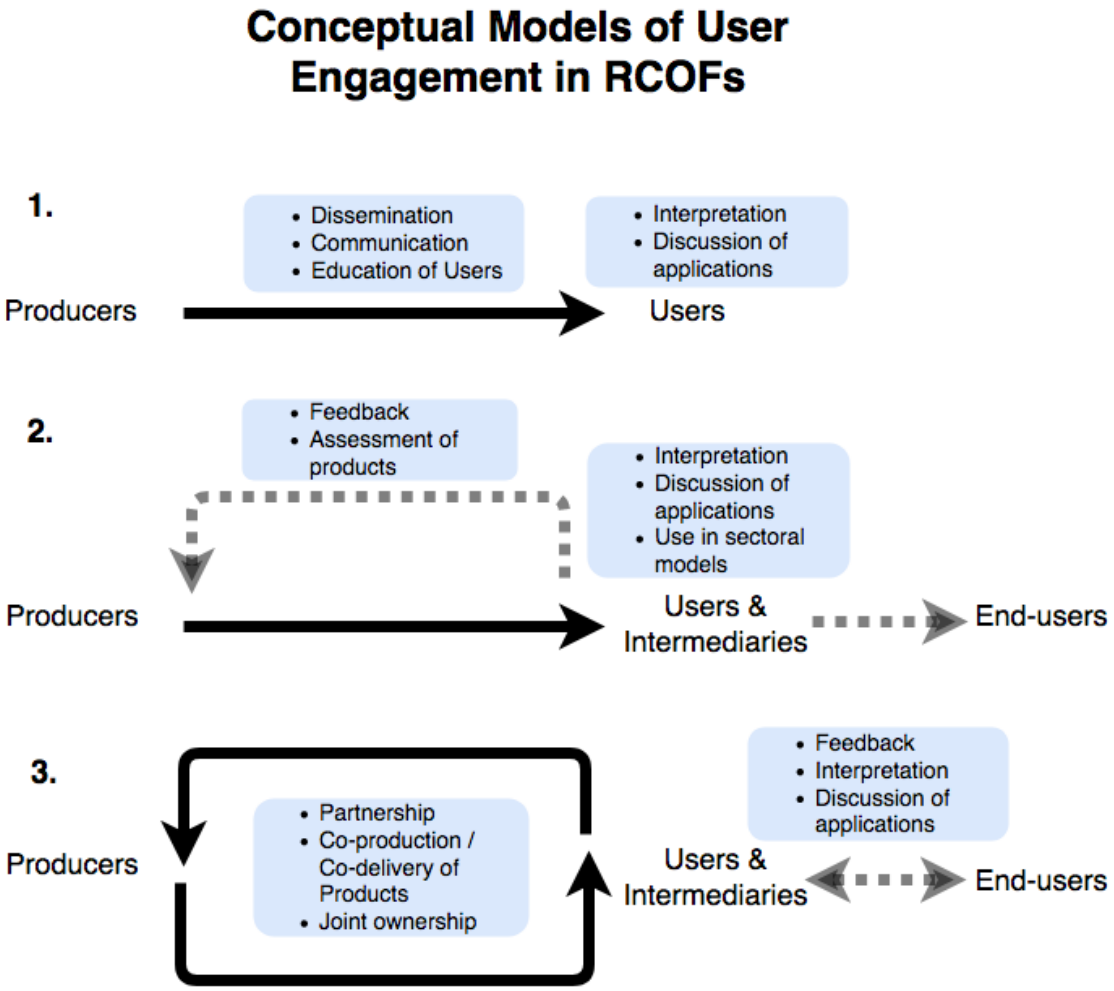

Figure 4: Conceptual models of user engagement in the RCOFs (solid lines indicate well established/formalized relationships, whereas dashed lines indicate less formal or informal relationships)

While no single RCOF exactly emulates any one of these conceptual models (indeed, most incorporate various elements of multiple of these), they provide a helpful heuristic for understanding how user engagement has been framed and discussed. Currently, there are very few RCOFs that have embraced fully collaborative models of user engagement (depicted in model #3). The majority of RCOFs are operating more closely in line with models #1 and #2. In most cases, interviewees expressed a desire to move beyond purely linear approaches (depicted in model #1) to incorporate feedback loops and intermediaries as part of a multi-step chains of information production and delivery (as in model #2); however, this aspiration can be difficult to realize in practice (as will be discussed further in Section 4.4).

These different models of user engagement are carried out through a variety of practices (See Table 2). In most RCOFs, potential users are, at the very least, invited to attend the RCOF forum meeting; however, in several regions, there are currently no users participating in the forum at all [Int. 6, 19] – e.g. FOCRA-II and NEACOF forums, covering Asia and North Eurasia respectively (WMO, 2017). In other cases, user participation can be passive and does not guarantee the development of multi-directional communication, mutual understanding, inclusion of different knowledges, or establishment of relationships and respect between participants.

Current Modes of User Engagement in RCOFs	
Model #1	No participation
	Unidirectional 'transfer' of knowledge – i.e. dissemination
	Training in interpretation of forecasts
	Sectoral interpretation of forecasts
Model #2	Application within sectoral modelling
	Review of previous forecasts & evaluation of applications
	Boundary organizations & intermediaries
	Sectoral user forums – e.g., health, food security, water, agriculture
	Inputs & feedback toward tailored products
	Follow on activities – e.g. contingency planning, agricultural planning workshops
Model #3	Support & investment – e.g. financial, human-resource, in-kind
	Produce new products using the forecast input – e.g. food security outlook
	Co-production and / or co-delivery of products – e.g. sector-specific bulletins, advisories

Table 2: Current Modes of User Engagement in the RCOFs and Related Conceptual Models

Some RCOFs integrate sessions during the forum for different sectors to interpret, discuss, and assess the implications of the forecasts for climate risk management. Some regions organize dedicated 'user forums' are held as stand-alone events following the RCOF. For example, in some regions in Africa, Malaria Outlook Forums have been held following the RCOF, where health professionals use the forecast to assess the likelihood of malaria incidence and actions that could be taken to minimize outbreaks (Patt, Ogallo, & Hellmuth, 2007). Similar sector-based user forums have been organized for stakeholders in food security, health, water management, and disaster risk reduction and management [Int. 1, 14, 15], (see also WMO, 2012).

In several cases, feedback from users has driven the development of new climate information products. For example, in the Greater Horn of Africa region, requests from users have prompted the provision of new types of parameters within the seasonal climate outlook (e.g. seasonal rainfall totals). There are also some examples of dedicated training for users and dissemination sessions with the media or other communications experts (e.g. media training, press releases) to improve interpretation and communication of the forecasts (WMO, 2016). Many RCOFs employ multiple forms of user engagement across this spectrum; however, the manner in which users are involved can vary from year to year, often due to availability of funding.

4.3 Persistent Challenges to User Engagement in RCOFs

Identifying Users and Understanding Decision-making Contexts

Despite ongoing efforts toward user engagement, challenges remain. An early review of RCOFs following the 1997/98 season observed that "it was not clear who the users were, or should be, or what their needs were, or how to engage actual and potential users in the Forums" (Basher et al., 2000, p. 12). Twenty years later, debates about which users *should* be engaged within RCOFs, as well as what their needs are, have continued. For example, during Global RCOF Review held in September 2017, the question of who the users of RCOFs are (and should be) was taken up. Thus, while the climate science community is increasingly embracing the idea of working with users, the issue of identifying potential users, assessing their specific needs, and understanding their decision-making contexts remains a stumbling block.

To date, potential users have generally been depicted in broad terms. For example, four categories of users of RCOFs have been described, including: individual 'end-users'; intermediaries or extension agents; media; and experts who use RCOF products as inputs to application models WMO, 2008, p. 2). Alternatively, RCOF users are grouped by sector, with agriculture and food security, health, water resources, disaster risk reduction and management, and energy being the most frequently represented (WMO, 2016). There are also important questions about the institutional scale at which users should be involved. Thus, despite broad assumptions about the kinds of users that might benefit from RCOF outlooks, these categories remain quite general and users are treated monolithically. As recounted by one interviewee:

> Of course, 'users' is a vast area. You can get representatives of users, but if it's only representatives then they've got to transfer the information on down the chain until it finally gets to the dam operator or the farmer or whoever it is. Just talking about the 'user' in the generic sense is actually easy. But to do it in practice, to the ground level, is difficult. [Int. 8]

Lack of specificity and confusion about how to effectually identify *actual* users has, to date, limited involvement of users and prevented assessment of their needs in many locations.

In most RCOFs, the representative users come largely from national-level organizations. For example, in the Mediterranean region, there are currently no regional-scale users who participate, but national-level users from the host country do attend the forum meeting. Thus, there can be mismatches between the geographical or institutional scale of information being provided and the potential scale at which users make decisions [Int. 19]. As such, many respondents questioned the value of involving 'end-users' within the regional forum and, instead, felt that involvement of users could be more productive, beneficial, and efficient at the national or sub-national level [Int. 1, 6, 13 17, 18], (see also WMO, 2017). Nonetheless, several participants in the RCOF Global Review Meeting stated that the attendance of national-level participants may still provide useful opportunities for interaction; however, this is likely to be highly context- and sector-dependent (e.g. in some cases national-level water managers may rely heavily on regional-scale climate information in regions with large trans-boundary river basins).

Differences in user engagement also reflect the regional diversity of RCOFs – including historical, institutional, and political contexts, which fundamentally shape the landscape of potential users. Some regions have well-established users at the regional scale, while others do not. As noted above, this has resulted in a growing interest on engaging with users more extensively within national-scale processes in many regions, rather than attempting to develop user engagement at the regional scale within the RCOFs [Int. 2, 13, 14, 16, 17, 18] – for example, there are now a growing number of National Climate Outlook Forums that include efforts to engage national and sub-national stakeholders. Nonetheless, even when there are clearly identified regional-scale users of the RCOF forecast, it remains difficult to determine what kinds of specific products and services they need. At the most basic level, inadequate or intermittent funding for the RCOFs means that it can be difficult to enable users to participate in the meetings on a regular basis [Int. 1, 18], thereby limiting iterative interaction and two-way communication. Further, it has been shown that users have difficulty communicating their needs (Vincent, Dougill, Dixon, Stringer, & Cull, 2015), thereby necessitating concerted effort and, often, multiple approaches to elicit meaningful information about the kinds of information that is required (Daly, West, & Yanda, 2016). As such, assessing users' needs is a time- and resource-intensive task, making it prohibitive for many RCOFs to carry out in a systematic way [Int. 2].

Additionally, respondents emphasized that in many regions, the NMHS *themselves* are the main participants and, therefore, the primary users or beneficiaries of RCOFs. As discussed in Section 4.1, the RCOFs are a key mechanism for building capacities and networks among NMHS in the region, as well as a platform for discussing and resolving challenges to regional forecasting, advancing new forecasting methods, and sharing new and cutting-edge research. In this way, even when 'users' are not involved directly in the RCOFs, NMHS still benefit greatly, which can translate to indirect benefits to other stakeholders at other points in the service delivery chain.

Demonstration of Value and Sustainability of the RCOFs

The sustainability of the RCOFs is a problem that was identified at the outset (Basher et al., 2000; NOAA, 1998), which has implications for whether and how users are involved.

It is often expensive to bring users to RCOF meetings from across the region and, therefore, financial constraints are often a key barrier to consistent user involvement. Yet, many individuals and organizations involved in the RCOFs see the problem of the sustainability of the RCOFs as being fundamentally linked to the issue of demonstrating their socio-economic benefits. This framing reflects a series of causal assumptions about the linkages between the value and sustainability of the RCOFs: 1) the sustainability of the RCOFs is dependent upon demonstrating the value of the forecasts, 2) the value of the forecasts can only be realized through the use or application of forecasts, and 3) the successful use of forecasts hinges on engagement with users. The 2008 RCOF Review summed up this line of thinking:

> The best way to convince users, involve governments authorities, media, private sector and others is by demonstrating the effectiveness of climate applications…once the results are evident, additional support will come from partners who become more motivated to scale up pilot projects to other locations and/or development sectors. (WMO, 2008, p. 7)

Similarly, one interviewee noted that "if you can actually demonstrate that these [RCOFs] are producing value, then funding, in principle, should become more straight forward" [Int. 11]. Furthermore, the predicament of NMHS has been presented as a "vicious circle": when the climate services provided are of low quality, this discourages further investment, and, as a result, the services never improve. Increased capacities to meet users' needs are considered essential to "reverse the cycle" (Martinez, 2017). Thus, the notion that issues of user engagement, demonstration of value, and sustainability of the RCOFs are fundamentally intertwined was a dominant problem-framing expressed across the various data.

However, some respondents questioned the logic and practical implications of these assumptions. Further, some emphasized the importance of interrogating what is meant by 'value' and how this should be measured. While much emphasis has been placed on assessing the value of climate services in purely economic terms (see, for example, WMO, 2015), this is just one way of conceptualizing the value of seasonal climate forecasts (Bruno-Soares, et al., Submitted). Several interviewees felt that a singular focus on economic valuation was overly narrow. For example, one respondent explained, the RCOFs are "really worthwhile," not for "actually producing an outlook," but for creating opportunities for "co-learning" among climate experts and for "bringing people together to share experiences on how they are doing their outlooks and how they are actually communicating with their end users and doing tailoring and all that good stuff" [Int. 13]. It was further recognized that "value doesn't always mean dollars" [Participant in RCOF Global Review] and that the RCOFs produce many benefits that are "intangible" [Int. 17] or otherwise difficult to measure quantitatively. Several respondents suggested that value of RCOFs should be considered in terms of other metrics, such as how they have increased forecasting and prediction capacities, particularly in developing countries [Int. 2, 8].

5. Discussion: Learning from the RCOFs

Key Lessons Around User Engagement

A key finding emerging from this research is that how users are engaged in RCOFs is highly variable from region to region. This fact may be explained by differences in the priority placed on user engagement relative to the other goals of the RCOFs, whether or not there are clearly identified users at the regional scale, as well as how the RCOFs align with or build upon existing regional institutions and modes of cooperation. For example, in some cases, the scale of the forecast may better coincide with the geographic and institutional scope and mandates of existing organizations, and, thereby, naturally fit with the scale of policy formulation, decision-making, and action. This can increase the demand for regional-scale information and the possibility of productive interaction with users of forecasts – though this alone is not sufficient to ensure that climate information will be taken up in practice (Patt & Gwata, 2002). However, regional differences have not, to date, been explicitly addressed within discourses around user engagement; rather, users are often referred to monolithically with little acknowledgement of the regional heterogeneity of the RCOFs. Thus, as RCOFs are being formally incorporated into WMO's multi-level climate services infrastructure, there is a need to consider how they interact with and continually evolve in response to existing capacities and the broader institutional landscape in each region and what this will mean for user-engagement and co-production of climate services in the future.

Findings also indicate the need to further explore questions about where, when, how – and even *whether* – user engagement is needed, e.g. what is the 'appropriate' scale at which users should be involved? Our analysis indicates that there is likely no single or correct answer to these questions. The ways in which user engagement should be undertaken will be highly context-dependent. As such, there is no 'best' way of engaging users and it would not make sense for all RCOFs to engage users in the same way.
Given the regional scale of the information, it is not likely to be practical or desirable to include (often idealized) representatives of local 'end-users' (e.g. small-scale farmers, livestock keepers, etc.) in RCOFs. Instead, each RCOF must assess what kinds of stakeholders, partners, and potential users exist in their regions and to adapt their efforts accordingly. Thus, it will be important to understand and effectively leverage different strengths and capacities of stakeholders across regional, national, and sub-national scales within each region to develop smarter and more targeted approaches for cooperation. For example, experiences in the United States have shown the value of developing "boundary chains" (Lemos, Kirchhoff, Kalafatis, Scavia, & Rood, 2014), in which organizations that operate at the science-society interface help to facilitate linkages and networks to increase the reach and usability of climate information among a broader base of potential users, while also enabling institutional adaptability and reduction of transaction costs.

However, it is also important to note that not all stakeholders see user engagement as a primary function of the RCOFs, but rather emphasize the role of the RCOFs in enhancing national-scale capacity, scientific networking, and producing regional consensus

forecasts. This reflects the notion that in order for scientists to effectively engage with users, they must first have sufficient technical capacities. Thus, in some regions, the production of the regional seasonal forecasts instead serves largely as an organizing principle that enables regular, incremental progress against broader goals that are ancillary to the production and delivery of climate services more generally (e.g. capacity building, scientific consensus), even if the products of the RCOFs themselves may not always directly improve climate risk management without further interventions at lower institutional scales.

As these results have shown, there is also a pervasive belief that the value and sustainability of the RCOFs are fundamentally linked. Measuring the value of the seasonal climate outlooks has been a desire since the inception of the RCOFs (NOAA, 1998). Yet, sustainability and self-sufficiency of the RCOFs has been a consistent, but elusive, goal (Buizer et al., 2010; Gerlak et al., 2017) There is a pervasive belief that demonstration of the value of climate outlooks will spur further investment in the RCOFs. Despite this, there has not yet been a coordinated effort to systematically document the benefits or measure the value of the RCOFs or their products (Gerlak et al., 2017). The lack of systematic assessment likely reflects the fundamental difficulty of measuring the socio-economic value of seasonal climate forecasts (Bruno-Soares, Daly, & Dessai, Submitted) and of evaluating climate services more generally (Vaughan & Dessai, 2014). However, this is further complicated by challenges to identifying specific users and understanding their needs in many regions – i.e. if we don't know who the users are, how can we assess the value of the forecasts for their decisions? Thus, the logic of relying solely on evidence of the (economic) value of forecasts to trigger investment and to solve the problem of the sustainability of RCOFs falls short on multiple accounts.

In contrast to expectations that RCOFs will generate socio-economic value *directly* through the application of the regional climate forecast itself, our analysis indicates that the benefits of the RCOFs are often realized *indirectly* through the increased capacities of NMHS to produce scientifically credible forecasts, as well as generate social learning about new strategies for engaging with users and other stakeholders to make them more usable for decision-making at national and sub-national scales. The benefits of the RCOFs are diffuse and, therefore, even more difficult to measure and attribute – challenging the notion that simple measures of 'value' will be sufficient to spur sustained investment. It will be important to develop new approaches for conceptualizing and assessing the value of the RCOFs within a multi-level chain of climate services production, delivery, and use. There is also a need to be clear about what the RCOFs can and should be expected to deliver. This will involve clarifying goals, roles, responsibilities, and expectations of all actors throughout the climate services delivery chain. This may ultimately require reframing the goals of the RCOFs, as well as how their value is assessed, how this is communicated, and to what audiences.

Implications for Co-production of Climate Services

Co-production in the field of climate services is predominantly conceptualized as iterative collaboration between producers and users to enhance the production of 'usable' climate information (see, for example, Dilling & Lemos, 2011; Meadow, Ferguson, Guido,

Horangic, Owen, & Wall, 2015a). It is, therefore, not surprising that co-production in the RCOFs is framed primarily in terms of increasing user-producer interactions. However, this is a narrow theoretical interpretation that does not fully recognize the multiple 'lenses' through which co-production of climate knowledge can be understood (see Bremer & Meisch, 2017 for further discussion). Further, experience has shown that simply putting people together is not sufficient to enable the co-production of usable knowledge (Lemos, 2015). Other attempts to increase public participation in scientific decision-making have demonstrated the uncertain and unexpected outcomes of participatory processes (Chilvers & Longhurst, 2016). We argue that user engagement should not be treated as synonymous with co-production, and that there is a need for more flexible interpretations of co-production that reflect the heterogeneous and dynamic landscapes of climate knowledge and stakeholders in various regions.

First, equating interaction between 'users' and 'producers' with co-production unnecessarily delimits the scope and opportunities for co-production at other points throughout the climate service delivery chain, as well as who should be involved and how. As discussed in Section 4.1, some respondents felt that NMHS may actually be the primary beneficiaries of the RCOFs. Beyond the value of participating in trainings, capacity building, and expanding their professional networks through the RCOFs, NMHS benefit indirectly by enhancing the credibility of their own forecasts. These interactions among scientists don't always involve what would conventionally be considered climate information 'users.' However, when considered in light of broader interpretations of co-production that emphasize transdisciplinarity (Pohl et al., 2010; Polk, 2015), social learning (Akpo, Crane, Vissoh, & Tossou, 2015; Dale & Armitage, 2011), and cross-scalar interactions of knowledge systems (Cash et al., 2006), the networking and consensus forecasting components of the RCOFs can be considered processes of co-production in their own right – even when there are no 'users' present – by bringing together experts from different institutional scales, who possess different expertise and come from different educational, social, and cultural backgrounds.

Second, RCOFs do not operate independently, but are increasingly integrated within a multi-tiered climate services delivery system under WMO and the GFCS (WMO, 2003; 2011). While at the outset, the RCOFs were the 'only game in town,' the institutional context for climate services production has changed dramatically over the last 20 years and the objectives of the RCOFs should be adjusted accordingly. Within this rapidly evolving institutional landscape, it will be important to recognize that RCOFs are just one step in a multi-level process of producing usable climate services. RCOFs are unlikely to bring about the desired end-goals of improved climate risk management and climate adaptation without developing or strengthening linkages with institutions, networks, and processes at other institutional scales. As such, RCOFs cannot and, indeed, *should not* be expected to do everything. In the context of the WMO's efforts to strengthen and build climate services infrastructure spanning global, regional, and national levels, RCOFs can thus be seen as providing essential linkages between global and national organizational structures knowledge and information. There is thus a need for more complex, multi-sited conceptualizations of co-production of climate services, as well as new kinds of cooperation and partnership that will be needed (e.g. boundary chains, as discussed above).

Recognizing that there may be multiple sites of co-production along the climate service delivery chain will have important implications for how we evaluate the RCOFs, as well as how to undertake user engagement and co-production in the future. This is not to say that it will not be important to involve 'traditional' users, such as sectoral representatives, in the development and delivery of climate services. Rather, it is a call to apply more nuanced conceptualizations of who potential users are, to acknowledge how historical and institutional contexts shape possibilities for co-production, and to avoid making overly broad generalizations about users and their needs. Therefore, our findings indicate there is a need for more deliberate and contextualized approaches to involve users, along with more careful consideration about *when, where, why, and how* co-production is undertaken.

6. Conclusion

In this paper, we have examined the role of user engagement within RCOFs over the last 20 years, as well as persistent challenges to these efforts. Our results highlight that it is difficult to make generalized statements about the role of user engagement across the RCOFs due to their diversity, which reflects their different histories, contexts, evolutions, and trajectories. We find that it will be necessary to more explicitly recognize and account for the diversity of the RCOFs—a strength that has allowed the RCOFs to successfully expand to many regions around the globe, but also an attribute that precludes 'boiler plate' approaches to user engagement and, ultimately, co-production. Furthermore, we conclude that embracing more fluid interpretations of co-production, which are not limited to interactions between 'producers' and 'users,' may help to illustrate the multiple benefits of RCOFs. While user engagement and co-production are generally portrayed as a solution to the challenges of demonstrating the value and sustainability of the RCOFs, this assumption oversimplifies the objectives and benefits of the RCOFs, as well as the complexities of user-producer landscapes in each region.

The fact that there is not a singular approach to user engagement that will be effective in every RCOF is not a surprise, and reflects the broader literature on co-production (Bremer & Meisch, 2017; Meadow, Ferguson, Guido, Horangic, Owen, & Wall, 2015b; Schuttenberg & Guth, 2015). However, it does imply that the ways in which we talk about user engagement in RCOFs, as well as the expectations and the goals of the RCOFs, should be adjusted in response. We argue that it will be important to more clearly articulate the multiple goals and benefits of the RCOFs within a multi-level chain of climate services production and delivery, as well as generate refined understandings of potential regional users and their decision-making contexts. This will enable more contextual and nuanced approaches to user engagement and co-production that may enhance societal benefit from climate information and services.

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