Examining the Goals of the Regional Climate Outlook Forums: What Role for User Engagement?

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(Manuscript received 15 February 2018, in final form 28 June 2018)

ABSTRACT

Over the last 20 years, Regional Climate Outlook Forums (RCOFs) have brought together scientific experts and stakeholders to produce regional-scale climate information products for society. This article examines the goals and practices of RCOFs, with a focus on user engagement, in order to draw out practical lessons for future implementation of RCOFs. Analysis of literature and documents ($n = 72$), interviews with key informants ($n = 25$), and participant observation were used in this research. Results show that approaches to user engagement in the RCOFs vary significantly from region to region and have been shaped by differences in the priority placed on user engagement relative to the other goals of the RCOFs, the role of RCOFs in the broader climate services delivery chain, the landscapes of potential users and institutions, and views about what the role of users can and should be. Findings indicate that approaches to user engagement necessarily reflect the regional context. This research suggests that more reflexivity about the current framing of RCOF goals is needed, including how users can and should be involved within RCOFs and how the benefits and value of RCOFs are conceptualized, assessed, and communicated in the future.

1. Introduction

Over the last decade, the concept of climate services has gained increasing popularity (Brasseur and Gallardo 2016). The growing interest in climate services is indicative of broader efforts 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. Yet, on their own, climate forecasts do not have any "value" per se; it is only through the *use* of climate information for decision-making that value can be derived (Murphy et al. 2001). At the same time, incorporating scientific climate information within decision-making remains a persistent challenge. The difficulty of linking seasonal climate forecasts with societal applications was acknowledged early on (Glantz 1977), but was more fully realized through early attempts to practically use seasonal climate forecasts in the late 1990s, when a range of barriers was identified (Troccoli et al. 2007; Murphy et al. 2001; Vogel and O'Brien 2006).

To improve the uptake of science within societal decision-making, it has been proposed that there is a greater need for "long-term dialogues and interactions" between "producers" and potential "users"[1] of scientific knowledge (Mitchell et al. 2006, p. 324). The basic

Denotes content that is immediately available upon publication as open access.

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DOI: 10.1175/WCAS-D-18-0015.1

[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 coproduction efforts and are even counter to the notion of coproduction 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.

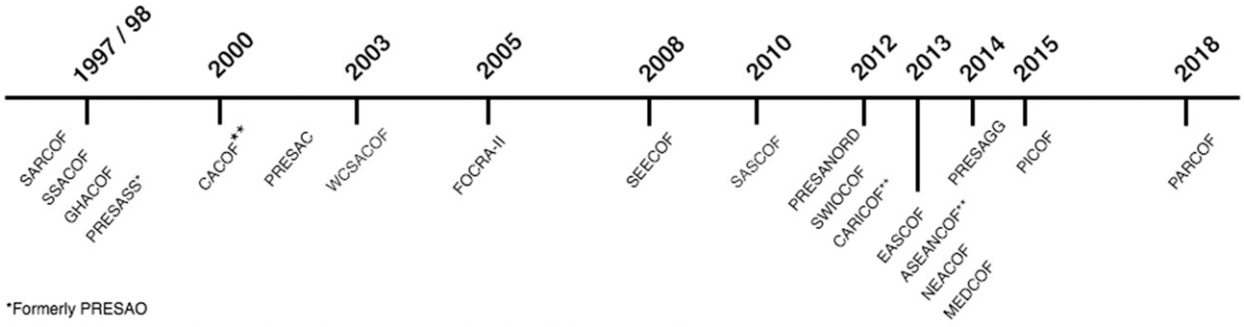

FIG. 1. Timeline of the establishment of RCOFs globally (NOAA 1998; WMO 2016, 2009a). (Source: WMO website: https://public.wmo.int/en/our-mandate/climate/regional-climate-outlook-products.)

premise of increasing interaction between producers and users has been around for several decades in the area of climate information (see, e.g., NOAA 1998; WMO 1997). However, how processes of user engagement are conceptualized and implemented will have important implications for whether or not they will contribute toward the production of knowledge that is "usable" for decision-making and action (Daly and Dilling 2018, manuscript submitted to *Climatic Change*).

In this paper, we seek to understand how user engagement has been framed and undertaken 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 formal mechanisms for sustained interaction between producers and users of seasonal climate forecasts and are now conducted in 20 regions across the globe. RCOFs, therefore, provide a valuable opportunity to learn and provide broader insights for the field, which is still assessing how best to engage with users 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 meeting to review 20 years of RCOF activities. 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 section 3, we describe the methods used to conduct this analysis. In section 4, we present the results of the research, responding to these two questions: 1) What are the goals of the RCOFs? and 2) How are users currently engaged in the RCOFs? In section 5, we discuss perceptions of persistent challenges faced within the RCOFs and implications of these findings for user engagement within RCOFs in the future. Section 6 provides concluding remarks.

2. The establishment and expansion of regional climate outlook forums

The RCOFs were conceptualized and initiated by the U.S. National Oceanic 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 et al. 2016). These initial RCOFs were backed by WMO (Buizer et al. 2016) 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 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 Fig. 1 for a timeline of the establishment of RCOFs). By February 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 of the globe (see Fig. 2), with some

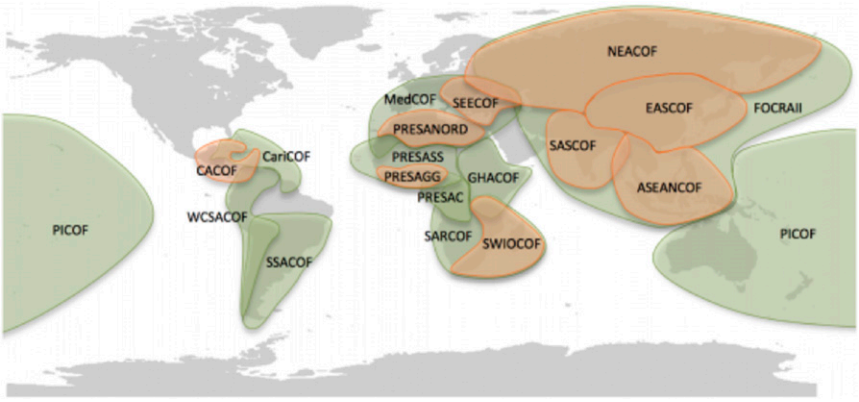

FIG. 2. Map of geographical coverage of the RCOFs (source: WMO website).

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. At the time of this writing, there are 20 RCOFs in operation (WMO 2017; see also Table 1).

As RCOFs have expanded, each has evolved independently to fit the regional context, including adapting to existing institutions, geopolitical relations, and modalities of cooperation in each location. However, there have been increasing efforts to standardize the RCOFs as they have become progressively more integrated within WMO's broader climate services infrastructure, which has three tiers: global, regional, and national (Brasseur and 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).

3. Methods

In this study, we examined the role of user engagement within the RCOFs over the last 20 years. 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 engage users in the development of climate services in the future.

To begin, we conducted a review of academic publications ($n = 17$), as well as gray literature and technical documents ($n = 55$), discussing the history and operations of the RCOFs. We analyzed these documents to identify the stated or explicit goals of the RCOFs, components and practices of the forums, and approaches to user engagement within the forums. Second, we conducted both semistructured and nonstructured 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, the lead author participated in and observed the 2017 Global RCOF Review, a 3-day meeting organized by the WMO to evaluate the current status and practices of the RCOFs across all regions, which was held in Guayaquil, Ecuador, from 5 to 7 September 2017.[3] This meeting included presentations reviewing the components and activities of all RCOFs (including explicit review of current efforts toward user engagement), as well as in-depth discussions and breakout group sessions. There were a total of 45 meeting participants from nearly 27 countries in attendance, which included representatives from all RCOFs, as

[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 subregional seasonal climate forecasts (WMO 2009a). The concept of WMO RCCs arose in the late 1990s, 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.

[3] http://www.wmo.int/pages/prog/wcp/wcasp/meetings/workshop_rcofs.php.

TABLE 1. Global overview of institutional landscape and coordination of RCOFs.

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 intergovernmental body
	PRESAC	Central Africa	WMO RCC, regional intergovernmental body
	PRESAGG	Gulf of Guinea countries	WMO RCC, regional intergovernmental body
	PRESANORD	North Africa	NMHS, WMO RCC Network, WMO RCC
	SWIOCOF	Southwest Indian Ocean and coast	WMO RCC, WMO GPC
	SARCOF	Southern Africa	Regional intergovernmental 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: North and Central America/Caribbean	CACOF	Central America	Regional intergovernmental 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 intergovernmental body, proposed WMO RCC Network, WMO GPC
Region IV: Europe	MEDCOF	Mediterranean countries	NMHS, WMO RCC Networks
	NEACOF	North Asia and north Europe	WMO RCC
	SEECOF	Southeast Europe	NMHS, regional research center
Multiregional	PARCOF	Arctic Council Member states	NMHS, proposed WMO RCC

well as individuals supporting the RCOFs at the global scale.

Within semistructured interviews, respondents were asked questions about 1) the history and evolution of RCOFs, 2) institutional arrangements and organizational roles supporting RCOFs, 3) goals of the RCOFs, 4) components and practices that constitute the RCOFs, 5) user engagement in RCOFs, and 6) efforts to evaluate the RCOFs. Semistructured interviews were conducted in person or via phone/Skype using a snowball sampling methodology, whereby the sampling frame was generated by first interviewing several key informants who were involved in the initial establishment of the RCOFs and continue to be actively involved in the implementation and coordination of RCOFs at the global scale. We then solicited recommendations for additional knowledgeable individuals who were involved in the early conceptualization of the RCOFs and/or currently play a key role in the coordination and implementation of the RCOFs to be included in the sample frame. We conducted a total of 15 interviews between January and August 2017, all of which were audio recorded and transcribed. An additional 10 nonstructured interviews were conducted through convenience sampling (e.g., at conferences and meetings); these were recorded through handwritten notes that were then digitized. Interviews were conducted until ''saturation'' was reached, such that interviews began to cover the same data repeatedly or else did not offer new data (see Rubin and Rubin 2012, p. 63).

This sampling methodology enabled representation of perspectives from a range of individuals across 1) various institutional scales,[4] 2) types of organizations, and 3) geographical and regional coverage. Of the total 25 interviews, 10 were conducted with individuals involved in RCOFs primarily at the global scale, while 15 were conducted with individuals involved primarily at the regional scale.[5] Ten interviews were conducted with individuals within national meteorological services, 11 with individuals based at international or intergovernmental organizations, and four with individuals based at universities or international research centers. Six of the interviewees were involved in the design and early implementation of the RCOFs (i.e., since their inception in 1997). Interviews were conducted with individuals who had *direct involvement in* all RCOFs, with the exception of those held in Sudano–Sahelian, central Africa, and Gulf

[4] Institutional scales here align with WMO's three-tiered climate services infrastructure (global, regional, and national; see section 1).

[5] Because some organizations play roles at multiple scales, they do not always fit in a single institutional scale (e.g., an individual in an NMHS can play a key role at the regional or global scale). Further, some individuals are directly involved in multiple RCOFs at the regional scale. Therefore, there is often overlap between levels and geographic scope of involvement.

of Guinea regions (i.e., PRESASS, PRESAC, and PRESAGG).[6] Attendance of the 2017 Global RCOF Review Meeting enabled further data collection across all 20 active RCOFs. Interview notes and transcripts and ethnographic notes were coded and analyzed using NVivo qualitative analysis software to identify emergent themes related to the goals, components and practices, and user engagement in the RCOFs.

4. Results

a. What are the goals of the RCOFs?

When they were first established, 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 as an important feature among many interviewees but was less extensively discussed in the literature. Implicit within the literature, interviews, and observation was the desired end goal of improved climate risk management and adaptation, even though this was rarely recognized as a stated, or explicit, goal of the RCOFs by WMO.

To date, however, there has been little clarity about how the multiple goals of the RCOFs fit together. 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, based on our analysis across multiple data sources, we consider these more specific goals to fall under and/or to support the overarching goal categories of 1) scientific consensus, 2) user engagement, 3) capacity building and networking,

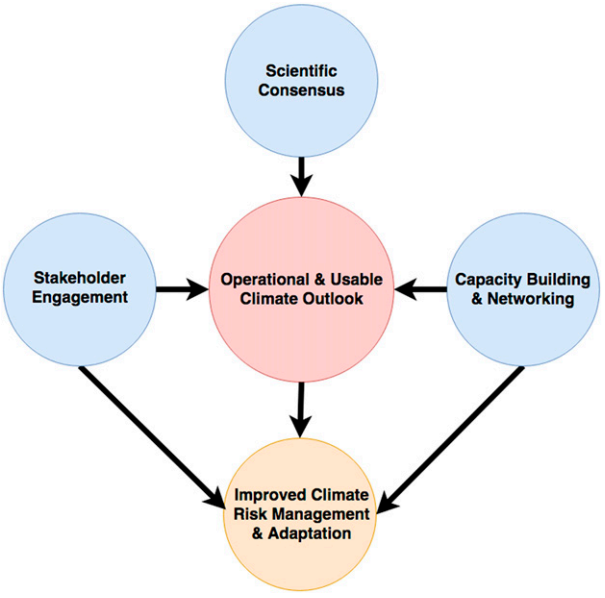

FIG. 3 . Goals of the RCOFs. Goals are based on stated goals of the RCOFs within literature and technical documents, as well as the perceived goals as expressed by interviewees involved in the establishment, coordination, or implementation of the RCOFs. Arrows indicate how various subgoals support or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

4) production of usable regional climate outlooks on an operational basis, and 5) improved climate risk management and adaptation. Within the overview of goals provided in Fig. 3, goals 1–3 are "contributing" goals, which support the "core" goal of the production of a usable, operational climate outlook. These contributing and core goals are ultimately intended to advance the ultimate "end" goal of improved climate risk management and adaptation (see Fig. 3).

In our analysis, we find 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. In the remainder of this section, we will discuss in further detail how each of these goals was variously interpreted by interviewees, as well how these goals relate to each other.

1) SCIENTIFIC CONSENSUS

While generally not overtly acknowledged within existing literature or technical documents [see Dilley (2000); Hansen et al. (2007); Orlove and Tosteson (1999) for exceptions], the RCOFs were perceived by interviewees to be a crucial mechanism for producing an *authoritative* regional climate forecast through a consensus process. Scientific consensus in the context of the RCOFs refers to the discussion and integration of multiple sources of climate-related data and forecast inputs from national, regional,

[6] 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 subregional forums, several respondents had direct involvement in the PRESAO precursor. Further, all of these RCOFs are currently coordinated by the African Center of Meteorological Application for Development (ACMAD), as was the PRESAO precursor, and interviews included multiple individuals involved in ACMAD and the PRESAO.

and global scales to produce a single regional forecast product. While the level of interaction involved in the consensus process can vary significantly from region to region, the consensus process generally includes the consideration of 1) the current and projected state of key regional climate drivers, 2) national-scale seasonal forecasts, and 3) regional- and global-scale seasonal forecasts, all of which are integrated through a process of subjective expert interpretation. This is why the product of the RCOF is generally referred to as the "consensus outlook."[7] 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—both among different scientists and between scientists and potential users. Emphasis is often placed on improving technical measures of the credibility of the forecast, often referred to as the "forecast quality."[8] 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 [Interviews (Ints.) 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 and Chidzambwa 2009).

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 in order to improve scientific credibility, as well as to 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 intended 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 (Ints. 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 (Ints. 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] Met Office or whoever sending the forecasts" (Int. 8). The consensus process provides a means for all countries to be directly involved in the production of the forecast, thereby increasing the legitimacy of the RCOFs.

2) USER ENGAGEMENT

User engagement is also seen as a contributing goal of the RCOFs. This ranged from simply building awareness of available climate information (Ints. 2, 14) to ensuring that potential users understand the limitations of scientific information to interpret it "properly" (Ints. 2, 14, 13, 16, 18). Building long-term relationships and

[7] 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 through a process of expert interpretation. 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.

[8] 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 and Mjelde 2002; Mjelde et al. 1993). While the notion of forecast quality may be particularly important to forecasters, it can often have little meaning to nonscientists, 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 nonscientists, rather than the narrower concept of forecast quality.

pathways for sustainable communication was also seen as a 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 (Ints. 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 way of enhancing the practical use of the information (Int. 14). Just as importantly, engagement with users was seen as building mutual trust among all participants (Participant at the Global RCOF Review Meeting).

3) CAPACITY BUILDING AND NETWORKING

RCOFs are also seen as key platforms for building regional and national climate prediction capacities and for facilitating knowledge exchange through intra- and extraregional networking. This was seen as particularly important among 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 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 new methodologies and the state of the art. Ideally, capacity building is intended to improve the scientific rigor of 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 (Ints. 14, 18).

4) PRODUCTION OF USABLE AND OPERATIONAL REGIONAL CLIMATE OUTLOOK

Unsurprisingly, many interviewees saw the production of an operational regional seasonal climate forecast, or "climate outlook," as being central to the RCOFs' activities (Ints. 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 (Ints. 1, 11, 14, 17), legitimate (Ints. 16, 17, 18), and salient (Ints. 1, 14, 15, 18)—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. Thus, the majority of interviewees felt that the production of the climate outlook was a central objective of the RCOFs, a sentiment that was widely echoed in analysis of RCOF literature and documents.

5) IMPROVED CLIMATE RISK MANAGEMENT AND ADAPTATION

As noted previously, the goal of improving climate risk management and adaptation is generally implied, rather than directly stated, in the majority of RCOF documents and literature. Based on the triangulation of multiple sources of data, we situate climate risk management and adaptation as the end goal, toward which all of the other RCOF goals are intended to contribute. RCOFs were first created out of a desire to manage the impacts of seasonal to interannual climate variability by "emphasizing the importance of understanding climate and how you can deal with climate risk" (Int. 13). Aldrian et al. (2010, p. 376) 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." 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 preemptive planning, decision-making, and action to mitigate or prepare for adverse impacts or else take advantage of climate-related opportunities (Ints. 14, 15).

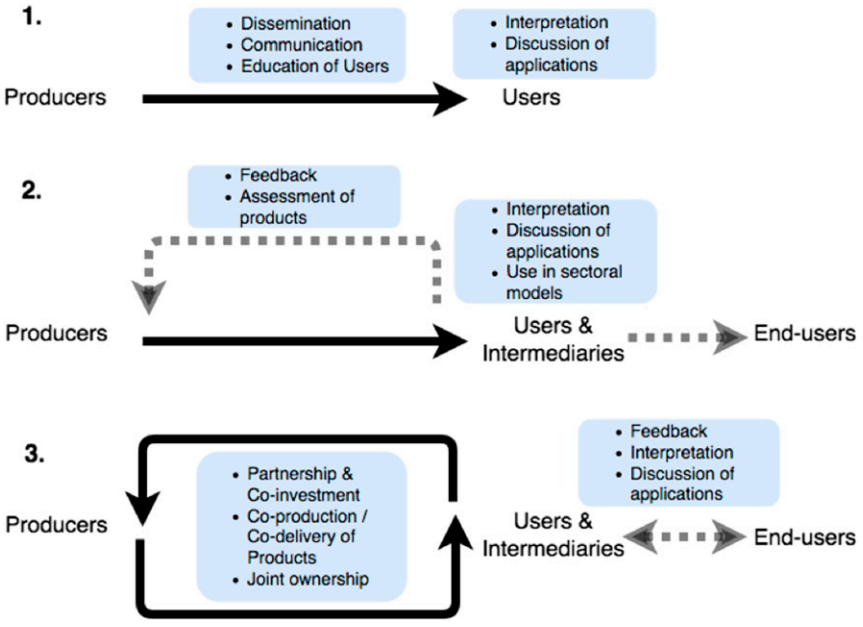

FIG. 4. Conceptual models of user engagement in the RCOFs. Solid lines indicate well-established/formalized relationships, whereas dashed lines indicate informal relationships.

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 interannual 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 multidecadal projections) in most RCOFs (Ints. 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 (Ints. 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).

b. *How are users engaged in RCOFs?*

Understanding differences in the relative importance of the various goals of the RCOFs helps to contextualize how user engagement has (or has not) been taken up within RCOFs, and why. Engagement with potential users was an early rationale for RCOFs (Basher et al. 2000; Buizer et al. 2016; NOAA 1998; Orlove and Tosteson 1999) and has gained importance as the RCOFs have increasingly become a central component of the GFCS, which is intended to create a structured means for producers and users of climate services to interact (i.e., through the development of the "user interface platform") to ensure that users' needs are being met (WMO 2011). However, as discussed in section 4a, not all stakeholders consider user involvement to be a central, or even an essential, component of the RCOFs. 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 Fig. 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 (Ints. 11, 9), but still presents a largely unidirectional relationship of information delivery. 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 (Ints. 2, 16). In some cases, this can also involve joint production and delivery of climate services products (e.g., risk analysis and tailored advisories), as well as co-investment and joint ownership of both the processes and products. Nonetheless, all models of user engagement, as currently implemented, engage users "downstream" of

the production of the forecast, thereby delimiting the ability of users to help define questions and needs to be addressed by RCOFs in the future.

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 implemented by individuals responsible for undertaking the RCOFs. According to interviewees, only a small number of RCOFs have embraced more collaborative models of user engagement (depicted in model 3). Nearly all RCOFs (with a few exceptions) are, thus, operating more closely in line with models 1 and 2. Many interviewees expressed a desire to move beyond purely linear approaches (as depicted in model 1) to incorporate feedback loops and intermediaries as part of a multistep chain 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 5d). Very few interviews ($n = 3$) or publications framed user engagement in highly collaborative terms, as depicted in model 3. Further, several respondents questioned the utility, and even possibility, of user engagement in line with model 3, since they were unsure of whether and how collaborative approaches to the production of the regional forecast could work and how this would impinge on the process of developing scientific consensus. This demonstrates the range of perspectives around how user engagement is framed within implementation RCOFs.

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 (e.g., FOCRA-II and NEACOF forums, covering Asia and northern Eurasia, respectively; WMO 2017; Ints. 6, 19). Nonetheless, even when users are involved, participation is often highly passive and does not guarantee the development of multidirectional communication, mutual understanding, inclusion of different knowledges, or establishment of relationships and respect between participants that is required for more collaborative approaches to producing the forecast and related climate information products.

Some RCOFs integrate sessions during the forum for different sectors to interpret, discuss, and assess the implications of the forecasts for climate risk management. For example, several regions organize dedicated "user forums" that 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 et al. 2007). Similar sector-based user forums have been organized for stakeholders in food security, health, water management, and disaster risk reduction and management in a growing number of regions (Ints. 1, 14, 15; see also WMO 2012).

TABLE 2. Current modes of user engagement in the RCOFs and related conceptual models.

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 modeling
	Review of previous forecasts and evaluation of applications
	Boundary organizations and intermediaries
	Sectoral user forums (e.g., health, food security, water, and agriculture)
	Inputs and feedback toward tailored products
	Follow-on activities (e.g., contingency planning and agricultural planning workshops)
Model 3	Support and investment (e.g., financial, human resource, and in kind)
	Produce new products using the forecast input (e.g., food security outlook)
	Coproduction and/or co-delivery of products (e.g., sector-specific bulletins and advisories)

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 and 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.

c. Persistent challenges to user engagement in RCOFs

1) IDENTIFYING USERS AND UNDERSTANDING DECISION-MAKING CONTEXTS

Despite ongoing efforts toward user engagement, challenges remain. A 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 the 2017 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 have been described by sector, with agriculture and food security, health, water resources, disaster risk reduction and management, and energy being the most frequently discussed (WMO 2016).

Nonetheless, these categories remain quite general and do not fully account for the complex networks of actors involved in climate services production, delivery, and, ultimately, use. For example, issues of the scale at which potential users operate and intrasectoral differences are not accounted for, which is to say that simply grouping users by sector can still be overly broad. Similarly, the category of ''end users'' does little to help develop sufficiently detailed understandings of decision-making contexts and climate information needs. 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)

When framed in general terms and without understanding specifically which individuals or organizations might benefit from the forecasts, as well as the various intermediaries involved in translating this information to end users, it is difficult to know *who exactly* should participate in the RCOFs in the first place.

Thus, there are important questions about which actors within the ''chain'' of climate information production, delivery, and use are the most important and appropriate to directly involve within RCOF processes. Likewise, there is a need for increased consideration of the appropriate institutional scale at which users should be engaged; users operating at national and regional scales are likely to have very different climate information needs, even if they are working in the same sector. 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). Nonetheless, there is currently little distinction made between national-scale and regional-scale users within discussion of user engagement in the RCOFs. Further, few RCOFs produce sector-specific forecast products, though there are some exceptions, such as Central America and the Caribbean, where producers have worked in close partnership with users to tailor, and even coproduce and co-deliver, sector-specific forecast products. For example, the Caribbean Institute for Meteorology and Hydrology, the RCC for the region, has developed formal agreements to co-produce and co-deliver tailored climate bulletins in partnership with regional organizations across six sectors (e.g., Caribbean Health Climatic Bulletin[9]). Overall, lack of specificity and confusion about how to effectually identify users has, so far, contributed to a dearth of detailed assessment of decision-making contexts and users' needs in many RCOF locations.

Differences in user engagement reflect the regional diversity of RCOFs—including historical, institutional, and political contexts, which fundamentally shape the landscape of potential users, as well as their decision-making contexts. Some regions have well-established users at the regional scale, while others do not. As a result, some respondents even questioned the value of involving users within the regional forum and, instead, felt that involvement of users could be more productive, beneficial, and efficient at the national or subnational level (Ints. 1, 6, 13 17, 18; see also WMO 2017). This has resulted in a growing interest in 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 (Ints. 2, 13, 14, 16, 17, 18). For example, there is now a growing number of National Climate Outlook Forums that include efforts to engage national and subnational users.

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

[9] See examples of the Health Climatic Bulletins for the Caribbean region here: https://rcc.cimh.edu.bb/health-bulletin-archive/.

funding for the RCOFs means that it can be difficult to enable users to participate in the meetings on a regular basis, and often different users attend from year to year (Ints. 1, 18), thereby limiting opportunities for iterative interaction and sustained relationships that can facilitate mutual trust and understanding. Further, it has been shown that users have difficulty communicating their needs (Vincent et al. 2017), thereby necessitating concerted effort and, often, multiple approaches to elicit in-depth understanding of the kinds of information that is required (Daly et al. 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 and their products. As discussed in section 4a, 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. Some NMHS also use the RCOF outlook product to inform or adjust their own national-scale forecasts. In this way, even when "users" are not involved directly in the RCOFs, NMHS still benefit greatly, which can translate to indirect benefits to users at other points in the service delivery chain.

2) USER ENGAGEMENT, DEMONSTRATION OF VALUE, AND SUSTAINABILITY OF THE RCOFS

The sustainability of the RCOFs is a problem that was identified at their inception (Basher et al. 2000; NOAA 1998). Issues of sustainability have direct implications for whether and how users are involved. It is often expensive to bring users to RCOF meetings from across the region; 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 issues of user engagement and demonstration of socioeconomic 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 cycle": 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" (Martínez Güingla 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. While much emphasis has been placed on assessing the value of climate services in purely economic terms (see, e.g., WMO 2015), this is just one way of conceptualizing the value of seasonal climate forecasts (Bruno Soares et al. 2018). Several interviewees felt that a singular focus on economic valuation was overly narrow and that process was as important as the products. 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 (Ints. 2, 8).

5. Discussion: Learning from the RCOFs

Examining the role of user engagement in relation to the other goals of the RCOFs helps to better understand and contextualize similarities, as well as differences, in how user engagement is understood and undertaken. Despite broad similarities in how user engagement is conceptualized and implemented, this research shows

that why and how user engagement is undertaken across the spectrum of these models varies widely from region to region. This can be explained by differences in terms of the priority placed on user engagement relative to the other goals of the RCOFs, the role of RCOFs in the broader climate services delivery chain, the landscapes of potential users and institutions, and views about what the role of users can and should be. We discuss each of these in turn, as well as their implications for efforts to engage users in RCOFs in the future.

a. Balancing multiple goals within the RCOFs

The importance placed on the production of the seasonal forecast as a core goal of RCOFs across both the literature and interviews is not surprising. This analysis shows that the production of the seasonal outlook serves as an organizing principle that supports antecedent goals, such as the consensus process, capacity building, scientific networking, and (in many regions) user engagement. Differences in the balance between the various goals across regions were evident, reflecting the different needs and priorities of each region, as well as particular individuals. For example, in regions where national-level capacities to produce climate forecasts are still developing or where drivers of seasonal climate are still uncertain, the consensus process and capacity building may receive greater emphasis. It is also clear that the consensus process and capacity building within RCOFs are important for enabling improved delivery of climate services at other scales (i.e., national and subnational). As discussed in section 4a, some respondents felt that NMHS may actually be the primary beneficiaries of the RCOFs.

To date, the goals of the RCOFs have only been loosely formulated, with little articulation of how the various objectives relate to each other or contribute to an overarching theory of change. In this paper, we have provided an overview of goals and their linkages (see Fig. 3) rooted in current RCOF goals and practices, as described in literature and documents, as well as by individuals responsible for RCOF implementation. This is meant to be descriptive, rather than prescriptive, and to serve as a starting point for better understanding the objectives of the RCOFs, as well as more clearly aligning RCOF activities with their goals. Such analysis has the potential to guide decisions about what interventions may be needed to improve the impact of the RCOFs in the future. However, this does not mean that all RCOFs do (or should) focus on all of these goals in the same way. For example, some regions may need to place greater emphasis on capacity building, while others may see user engagement as a more important priority in realizing the ultimate goal of improved climate risk management and adaptation. How these various goals are balanced and undertaken will depend greatly upon the specific technical, economic, and social contexts in each region.

b. Role of RCOFs in climate services delivery chain

Our results indicate that it is also important to recognize that the RCOFs do not operate independently. Rather, they are increasingly integrated within a multitiered 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. 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, as well as vital conduits for knowledge sharing. Within this rapidly evolving institutional landscape, it will be important to recognize that RCOFs are just one step in a multilevel process of producing usable climate services. RCOFs cannot and, indeed, *should not* be expected to do everything by themselves. As such, 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.

This also indicates that in contrast to the idea that RCOFs will generate socioeconomic value *directly* through the application of the regional climate forecast in all cases, the benefits of the RCOFs are often realized *indirectly*. This is especially true given that numerous interviewees felt that, in many regions, there were a very limited number of regional-scale users able to utilize the RCOF products directly. In a general sense, this indicates that there is a need for more nuanced framings of the benefits of RCOFs as part of a global climate services system, as well as a need to set realistic expectations about what RCOFs should be expected to achieve. Improved understandings of the multiple benefits of RCOFs—to both producers and users—can help to demonstrate important qualitative benefits that are not captured through economic valuation alone. This will be particularly important in locations where there are no regional-scale users.

c. Understanding users and institutional landscapes

Differences regarding the institutional landscapes and the users from region to region have not been explicitly addressed within discourses around user engagement in RCOFs, including how this may determine the

appropriate scale at which to engage users. In some regions, the scale of the forecast may better coincide with the geographic scope and institutional mandates of existing organizations. In cases where the RCOF forecasts have a more natural ''fit'' and ''interplay'' with existing scales of policy formulation, decision-making, and action, this can narrow the ''usability gap'' (Lemos et al. 2012). Higher levels of fit and interplay can, in turn, increase demand for regional-scale information and the possibility of identifying specific users of forecasts. For example, the RCOFs in the Greater Horn of Africa and southern Africa operate within designated Regional Economic Communities of the African Union, meaning existing institutions and scales of decision-making align more directly with the scale of RCOF forecasts. Not surprisingly, there are a large number of users participating in these forums. Conversely, in other regions, such as the Mediterranean or north Eurasia, where the forecasts cover much larger geographic areas that are not aligned with existing regional institutions, there are no clearly identified users of the regional products produced by the RCOFs.

Thus, it will be important to understand and effectively leverage different strengths and capacities of all stakeholders—both producers and users—across regional, national, and subnational scales to develop smarter and more targeted approaches for cooperation and modes of user engagement. At a minimum, this will require conducting scoping exercises and institutional analyses to assess who potential users might be and to understand specific decision-making contexts and information needs. In cases where there is a larger usability gap (i.e., when fit and interplay of existing information is low), there will be a greater need for interaction between producers and users to overcome barriers to use (Lemos et al. 2012).

d. Role of users in the RCOFs

The recognition that there is a need for greater interaction between producers and users to enhance the usability of RCOF products leads to this question: What *should* the role of users be within the RCOFs? And, based on this, what kinds of interactions between producers and users are needed and at what institutional scale(s)? While this analysis has provided a snapshot of how user engagement is currently framed and approached by those responsible for implementing the RCOFs, fundamental questions remain about which models of user engagement are most appropriate and what practices can best support them in the future. Answers to these questions will be highly context dependent, and user engagement strategies will necessarily evolve differently in each region.

However, what this analysis has shown is that user engagement within the RCOFs is currently framed quite narrowly, and, in practice, the role of users is often constrained to downstream involvement (i.e., after the forecast has been produced). Furthermore, inclusion of potential users has remained ad hoc, generally including users in an opportunistic manner (e.g., engaging national-level users from the host country on a rotating basis). Without long-term engagement of the same individuals and/or organizations from year to year, there is less likelihood of developing relationships and trust within and across producer/user communities. Such factors may contribute toward the perpetuation of linear modes of information production and delivery (i.e., models 1 and 2), rather than enabling opportunities for more collaborative approaches of coproduction, co-delivery, and co-investment (i.e., model 3).

Approaches such as coproduction can build joint ownership among producers and users of both the *problem* and *process* of developing usable climate information and services (Dilling and Lemos 2011); however, this may also entail radically reframing what the role of users can and should be within the RCOFs. For example, this may include greater ''upstream'' involvement of users, whereby they can help to jointly define goals and questions to be addressed through RCOF processes alongside climate information producers. Additionally, it will require creating space for reflection and dialogue on all sides, as well as increased transparency from producers about realistic time horizons for developing new climate information products and fundamental limitations of climate science to meet users' needs. It is through iterative, long-term discussion that trust and a shared sense of ownership can be built. Importantly, shared ownership will be key to spurring greater investment in and financial support for RCOFs among a range of stakeholders, thereby increasing sustainability of RCOFs in the future.

At the same time, it is also crucial to recognize that RCOFs cannot address the needs of all users at all levels. Indeed, in some regions where there are few or no regional users, it may be more effective to target engagement with users at the national, rather than the regional, scale. For example, a growing number of countries have developed National Climate Outlook Forums to interact with national-level users in recent years. In other cases, RCOFs might serve as a networking platform that can help to identify and include key ''intermediaries'' that can, in turn, expand the reach and usability of RCOF products to various ''end users.'' For example, experiences in the United States have shown the value of developing ''boundary chains'' (Lemos et al. 2014), in which organizations that operate at the science–society interface

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.

Conducting institutional and stakeholder analyses can provide detailed information about the existence of potential users and current institutional landscapes so that user engagement can be tailored to the regional context. More detailed understandings of the varying configurations of users and institutions within and across regions can help to ensure that RCOFs can better adjust their goals, approaches, and practices to effectively leverage existing regional capacities, as well as more effectively identify and address context-specific challenges to the development of usable climate services.

e. Implications for goals and practices of the RCOFs

In large part, the lack of coherence across the goals of RCOFs, approaches to user engagement, and assumptions about sustainability stems from the fact that RCOFs do not (to date) have a clearly articulated and rigorously formulated theory of change. It has been recognized elsewhere that climate services programs have often failed to clearly articulate goals and attendant theories of change, thereby limiting their effectiveness and impact (Tozier de la Poterie 2017).

If RCOFs are to deliver on the end goal of improved climate risk management and climate adaptation, it will also be important to more critically examine the RCOFs' practices in relation to their goals. Strengthening linkages between regional and national levels, as well as more clearly articulating the goals of the RCOFs, will be an essential first step. However, this will also involve clarifying roles, responsibilities, and expectations of all actors throughout the climate services delivery chain, as well as efforts to monitor and evaluate the RCOFs. Further, situating the RCOFs within the broader climate services system may even ultimately require reframing their goals, as well as how their value and benefits (both quantitative and qualitative) are assessed, how this is communicated, and to what audiences.

As part of this process, it will be vital to reconsider how user engagement is framed and implemented, as well as how this may ultimately support sustainability of the RCOFs, along with other desired societal benefits. Translating RCOF activities into improved climate risk management and adaptation will, in most instances, require more nuanced approaches to user engagement that build on in-depth analysis of users, their decision-making contexts, and information needs, as well as existing institutional contexts. This may go a long way toward improving the salience of the information provided to users. However, it is also recognized that knowledge must be considered sufficiently credible and legitimate among all stakeholders to be usable (Cash et al. 2003).

In many cases, processes of coproduction that enable sustained, iterative collaboration and equitable partnership are needed to enhance the credibility and legitimacy of both the RCOF products and processes. This will likely require more fluid and dynamic interpretations of coproduction that will be required at multiple points in the production and delivery of climate services. For example, while not currently recognized as such, the production of the consensus forecast can itself be considered a process of coproduction that enables the integration of a range of information, experience, and expertise—of both individuals and organizations—to enhance the credibility and legitimacy of the RCOFs among both producers and users. Similarly, capacity building and scientific networking are likely to generate positive benefits, even if these are indirectly realized. Thus, it will be important to take stock of both direct and indirect benefits derived through the various components of the RCOFs.

Further, taking insights about the importance of coproduction seriously will also mean moving beyond more passive conceptualizations of user engagement "downstream" of the forecast production (i.e., tailoring, formatting, and communication of forecasts after they have been produced). The production of usable knowledge may often require involving users "upstream" in the knowledge production process, whereby they become active collaborators involved and invested at all stages. This would include more open processes to enable producers and users to develop mutually agreed objectives of RCOFs, as well as jointly defined operational and research priorities. It is these more dynamic forms of collaboration that are likely to increase the joint ownership—and therefore sustainability—of both RCOF processes and products. However, this would require a departure from "business as usual."

6. Conclusions

In this paper, we seek to draw practical lessons from 20 years of RCOF implementation by examining the broader goals of the RCOFs, as well as how user engagement has been framed and implemented in the context of these multiple goals. We did so through a review of the literature and technical documents, interviews with key informants directly involved in the formation and implementation of the RCOFs, and participation in a global review of RCOF activities. We recognize that a limitation of this research is that these data primarily reflect the perspectives of climate

information producers (both individuals and organizations); however, because these individuals and organizations are those most involved in development and implementation of the RCOFs, their views are currently best situated to provide an understanding of goals and practices. While beyond the scope of this study, we recognize that it will be important for future studies to assess the views of current and potential RCOF users. However, as we have shown, a current barrier to conducting this type of research is the lack of defined, consistent users in many regions—a shortcoming that we hope may be addressed in the future.

Despite being one of the primary motivations for the creation of the RCOFs, user engagement has been interpreted and undertaken in very different ways from region to region. In part, this can be explained by differences in the relative importance of user engagement compared to other goals (i.e., scientific consensus, capacity building, and forecast production) that reflect the varying social, economic, and institutional contexts in each region. We argue that it will be important to more clearly articulate the multiple goals and benefits of the RCOFs within a multilevel chain of climate services production and delivery, as well as generate refined understandings of potential regional users and their decision-making contexts. In some cases, this may require a fundamental rethink of how the RCOFs should be organized and implemented and who should be involved, as well as how their benefits are conceptualized and measured as part of a multilevel climate services delivery system.

The fact that there is not a singular or "ideal" approach to user engagement in RCOFs is not a surprise and reflects the broader literature on coproduction of climate knowledge that emphasizes the context-dependent nature of all coproduction processes (Bremer and Meisch 2017; Meadow et al. 2015; Schuttenberg and 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. In many cases, this may require the development of more nuanced approaches to user engagement that may be more likely to improve usability of products, foster a sense of joint ownership, and enhance the sustainability of RCOF processes in the future.

Acknowledgments. Meaghan Daly and Suraje Dessai were supported by the U.K. Economic and Social Research Council Centre for Climate Change Economics and Policy (CCCEP) Phase II (ES/K006576/1). We thank Cathy Vaughan, as well as three anonymous reviewers, for their insightful comments, which greatly improved the paper. We also thank members of the Climate Change Adaptation Research Group at the Sustainability Research Institute, University of Leeds, for their helpful comments. Any errors or omissions that remain are the responsibility of the authors.

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