The Florida Water and Climate Alliance (FloridaWCA)

Developing a Stakeholder–Scientist Partnership to Create Actionable Science in Climate Adaptation and Water Resource Management

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ABSTRACT: The Florida Water and Climate Alliance (FloridaWCA) is a stakeholder–scientist partnership committed to increasing the relevance of climate science data and tools at time and space scales needed to support decision-making in water resource management, planning, and supply operations in Florida. Since 2010, a group of university researchers, public utility water resource managers and operators, water management district personnel, and local planners have engaged in a sustained collaboration for the development, sharing, and application of cutting-edge research to the practical issues of water management and distribution in the highly urbanized state of Florida. The authors, all members of FloridaWCA, present a case study of the organization’s history, its achievements, and lessons learned at the organizational, scientific/technical, and personal levels. Their goals are to 1) describe how the organizational process has contributed to actionable science based on posing and answering questions of importance; 2) share its scientific impact and technical contributions; 3) demonstrate the value of such a stakeholder–scientist partnership, and 4) identify organizational and structural components that have influenced its effectiveness, including personal reflections. The FloridaWCA, having reached its tenth anniversary, continues to evolve today as a sustained stakeholder–scientist partnership resulting in both guiding researchers of what is applicable in the field (creating an area of research that is useful to society) while also helping the practitioners to push the envelope on the state-of-the practices that can be informed by current research.

KEYWORDS: Adaptation; Climate services; Decision support; Risk assessment; Societal impacts
In 2015, the World Economic Forum identified the global water crisis as the most important challenge that the planet faced (World Economic Forum 2015). Water crises affect economies, environments, and societies, and are inextricably linked to failures of climate change adaptation. Addressing the global water crisis in urban areas is vital, given the increasingly large proportion of the global population living in urban centers; this is the first time in the history of humankind that half of the global population is living in urban areas [United Nations Department of Economic and Social Affairs (UN ESA); UN ESA 2014]. Moreover, while less than 3% of the global terrestrial surface is covered by urban areas, they are responsible for a majority of global resource consumption and carbon emissions (Brown et al. 2009). For these reasons, urban areas are emerging as “first responders” for climate change adaptation and mitigation (Rosenzweig et al. 2010).

The U.S. Census Bureau (2012) showed that Florida had the third highest urban population in the United States. The population of the state is increasing at an estimated 300,000 per year, especially along the coastal shoreline counties (NOAA 2013). In addition, the population of older adults (65 years or older) is also rapidly increasing in Florida (Carlson 2011). As a consequence, the responsibility of the water suppliers and managers who serve the domestic needs of this changing demography increases considerably, especially for a region like Florida, which has its fair share of extreme climate and weather events. Further complicating the matter is that only 5%–10% of the total rainfall contributes to the water supply. While Florida receives an average of 1,300 mm (52 in.) rainfall annually, about 70% is lost due to evapotranspiration. A small fraction of the remaining water is used in meeting other environmental needs like replenishing soil moisture deficits, restoring streamflow and lake levels. Furthermore, evapotranspiration increases with temperature. Therefore, the impact of increasing temperature from climate change can have significant impact in the hydrologic water balance and water availability for public supply in Florida.

Prior to the inception of Florida Water and Climate Alliance (FloridaWCA), survey results in the tri-state region of Alabama, Georgia, and Florida indicated a significant lack of use and awareness of seasonal climate and drought forecast information by water resource managers (Bolson et al. 2013). Seasonal climate forecasts\(^1\) are usually relevant to water resource supply and management at 3–12-month operational time scales. On the other hand, climate change projections\(^2\) are usually relevant to decisions on water permitting and capital planning, 20–50 years into the future. The survey results of Bolson et al. (2013) is a reflection of a broader issue across the United States where urban water systems are embedded in institutions that usually resist change, have limited understanding or awareness of the urban water system as part of the total hydrological cycle, and are led by elected officials with term limits that resist undertaking of risks and setting altruistic goals to preserve the

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\(^1\) Forecast is exclusively used for weather, seasonal, and decadal predictions that are critically dependent on the initial state of the atmosphere/climate system from where the prediction starts.

\(^2\) Projection, on the other hand, signifies an “estimate from an estimate” and is used in the context of climate change. Climate projection is an estimate of the future climate, which is strongly influenced by the estimates of the future greenhouse gas emissions. It is relatively less dependent on the initial state of the climate system from where the climate model is initiated for producing the climate projection.
ecosystem in and around the urban areas (Brown and Farrelly 2009; Farrelly and Brown 2011; Bolson et al. 2018). However, with rising awareness of urban water consumers about “green” approaches, such as sustainable development, there is a gradual attempt to cut wastage of water, recycle water, and thereby consume less of the freshwater sources (Gleick 2003; Chini et al. 2017). This has led to developing integrated concepts for urban water management, like the One Water approach (Paulson et al. 2017). In the One Water concept, water is valued from its source to its end uses, emphasizing on reuse and reduction of wastage through managing of the water in a holistic and sustainable way (U.S. Water Alliance 2016).

The FloridaWCA grew from a shared interest to understand these urban water supply and demand challenges to providing meaningful climate information and tools to public water utility managers in Florida. The current paper presents examples of the successful implementation of climate information in decision-making and contrasts it with challenges in incorporating such information by some of the utilities in the FloridaWCA.

The method utilized in this paper is the reflective case narrative. “Reflective case narratives are a practical mechanism for conveying lessons learned for practice improvement. Their ability to transform experience into knowledge in a colloquial, narrative style positions reflective case narratives as a powerful learning tool with pedagogical benefits for the evaluation community” (Becker and Renger, 2017, p. 138). Reflective case narratives are evaluative in nature. The motivation to conduct an evaluation in the form of a reflective case narrative arose from the authors’ intent to determine the effectiveness and impact of the 10-yr-old organization, as well as show how such a stakeholder–scientist partnership can contribute to actionable science.

The authors are all founding members of the FloridaWCA, and they all serve on the organization’s steering committee. Four of the authors are academic researchers at institutions of higher education (Irani, Misra, Martinez, and Graham), two are employees of public water utilities (Asefa, Morris) and one is the former project coordinator for the FloridaWCA (Staal). As such, the authors made the decision to focus their evaluation strategy on reflective narratives and a systematic, mutually developed framework to allow for the examination of factors that they thought were most relevant to the organization’s history, development, and success. In this approach the authors have provided their reflections on the development, processes, funding model, and specific stakeholder benefits achieved by the FloridaWCA. The authors acknowledge that they determined the criteria and produced the narratives that would be utilized to evaluate FloridaWCA. They argue that this approach was essential to accurately capture a decade’s worth of lived experience and analysis by the organization’s long-term members.

The authors’ decision to use a reflective case narrative was made during initial discussions of the evaluation strategy. To collect these data, all authors were asked to write a narrative based on their perceptions and experiences. The following series of reflective prompts were developed and utilized by the authors to develop their narratives that are also outlined in the following sections of the paper:

- History of FloridaWCA [why and how it got established; who were the original members? (“Inception of FloridaWCA” section)]
- What is the mission? (“Inception of FloridaWCA” and “FloridaWCA as a stakeholder–scientist partnership” sections)
- How is it organized? (“The facilitation process” and “Funding model of FloridaWCA” sections)
- What has been achieved? (“Advancement of actionable science in FloridaWCA” and “Stakeholder benefits from FloridaWCA” sections)
- Retrospectively, what have we learned? (“Discussion and conclusions” section)
Once the reflective narratives were written, the authors developed the structural framework for the study and organized the draft, which was reviewed systematically to insure veracity and clarity. One of the key lessons learned from this process was that although arduous, working from a reflective case narrative approach ultimately provided a rich, thick description of the unique scientist–stakeholder partnership which could serve as a potential model for adoption and adaptation.

**Development of FloridaWCA**

**Inception of FloridaWCA.** The origins of the FloridaWCA can be traced to Dr. Alison Adams, at Tampa Bay Water, who had been participating with a nascent (at that time in 2009) organization called the Water Utility Climate Alliance (WUCA; www.wucaonline.org). WUCA is a consortium of some of the largest water utilities in the nation with a mission to collaboratively advance climate change adaptation (Vogel et al. 2015). Dr. Adams hoped to bring together a similar sharing network for Florida water utilities in the absence of location-specific climate information for the planning and operations of Florida’s public water supply utilities. Therefore, the Water Institute at the University of Florida conducted preliminary surveys (Water Institute 2010) with the stakeholders to gauge interest for climate information. To conduct the survey, representatives from six public water utilities in Florida were asked via a phone survey about their interest in participating in a “climate impacts working group,” which eventually became the FloridaWCA. The results indicated that all of the utilities were interested in forming and participating in such a group. Their needs varied, however, according to their size, location, and geography, as well as water sources, fiscal, and regulatory distinctions. The respondents of this initial survey recognized this complexity, indicating that forming a stakeholder–scientist group would be valuable in terms of sharing perspectives and making the science actionable.

The FloridaWCA stakeholders included from the start academic partners, public utilities, local government, and Water Management Districts across the state (Fig. 1). Unlike WUCA, which is led by utilities rather than academics, FloridaWCA was established as a stakeholder–scientist partnership from its inception. All stakeholder member institutions of the FloridaWCA vary in size, service area, mission, and their sources of water, which can include groundwater, surface river, or desalinated water. It is interesting to note that at the time of forming the FloridaWCA, the state and the local governments had a directive to avoid the use of the phrase “climate change” in all official communications. Despite such resistance, the stakeholders expressed an interest in FloridaWCA, reflecting their genuine concerns of potential impacts of climate change and interest to make this truly a stakeholder–scientist partnership. The scientists that included meteorologists, hydrologists, and social scientists were equally open to forming this organization with an intent of carrying out their research “out to the field.” These initial perspectives evolved over time so that FloridaWCA became a stakeholder–scientist partnership and its members became eventual coproducers of information.

**FloridaWCA as a stakeholder–scientist partnership.** The experience of the FloridaWCA may be a useful model for others looking to bring together similar types of groups but it is in no way prescriptive. Although FloridaWCA has grown organically within an informal structure to create a shared learning environment, the core of its activities has followed the recommended practices of stakeholder–scientist collaboration identified in National Research Council (2009) and Beier et al. (2017). Some of these recommended practices include stakeholders clearly stating their needs, scientists understanding the stakeholder needs before suggesting or producing products, periodically having in person meeting with the partners to share information, and having a structured partnership including forming steering and advisory role.

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Scientist will be used in lieu of academic in the rest of the paper.
groups. It further suggests to iterate on the needs, methodology, data, and tools to generate the products, and share the risks involved in the decision-making and uncertainty attached to the products. Beier et al. (2017) indicate that these practices will likely grow and foster the capacity of such stakeholder–scientist partnerships. Unlike an outreach or a loading dock approach where science producers interact with stakeholders in a linear transaction (Cash et al. 2003, 2006), the shared learning network allows for iterative collaboration (Lemos and Morehouse 2005; National Research Council 2009; Dilling and Lemos 2011; Kirchoff et al. 2013; Nel et al. 2016). The outcome of such a collaboration is termed as coproduction from the stakeholder–scientist partnership [Advisory Committee on Climate Change and Natural Resource Science (ACCCNRS); ACCCNRS 2015; Beier et al. 2017]. However, in a comprehensive review study, Bremer and Meisch (2017) indicate that there are at least eight different flavors of coproduction in the climate change literature stemming from the different perspectives of the relationships between science, society, and nature. For example, some studies perceive coproduction as a way to empower traditional communities for climate adaptation (e.g., Kofinas et al. 2002). In other studies, coproduction is used in the context of understanding the coevolution of nature and society (e.g., Jasanoff 2010; Miller 2004). Similarly, Bremer and Meisch (2017) identify building adaptive capacity of institutions, enhancing public services, promote social learning, facilitate consultative interaction between consumers and producers of climate science, and integrating stakeholders in climate science research projects and climate scientists in decision-making process as other approaches of coproduction. FloridaWCA’s effort in coproduction met several of these classifications and they will become apparent from the discussions presented in the following subsections.

Fig. 1. The illustration of the scope and origins of the FloridaWCA members. Overlaid on a map of the water management districts of Florida (who are the regulatory stakeholders of FloridaWCA), the yellow spin wheel and the red dots on the map signify the academic or scientific and other stakeholder (potable water provider and utility) institutions, respectively.
The facilitation process. The purpose of establishing this partnership was to embark in coproduction of user-relevant data, tools, and information on climate variability and change through collaborative learning and shared dialogue. The facilitation process was informed by two theoretical foundations: experiential learning (Kolb 1984) and communities of practice (Wenger 1998), centered on an intentional experiential and iterative strategy to build cohesion and engagement among group members and to determine, address, and accomplish their interests (Fig. 2). Key to the process as outlined in Fig. 2 was 1) understanding the stakeholders, 2) assessing climate and decision-making tools, 3) evaluating the applicability of the tools, and 4) actual implementation of using the information.

Through the process of multiple full day, face-to-face workshops (21 to date), participants explored cutting-edge research in climate and communication and considered together their potential application to practical issues of water management and distribution in Florida. FloridaWCA workshops are held 3–4 times a year. The day-long workshops are a mix of formal presentations, group discussions and strategy sessions. The themes of the workshop are discussed by the steering committee of the FloridaWCA (comprising a member from each of the institutions) well in advance of the workshop with recommendations for speakers either coming from within the steering committee or from other members of the FloridaWCA. The workshops initially had around 25 people in attendance. That number has steadily grown over the years and 45 people attended the most recent workshop in January 2020. The member institutions have also been growing gradually over the years and currently represent a mix of water utilities, water management districts, and academic institutions (Fig. 1). The coordinator of FloridaWCA conducts the workshop and acts as the moderator for the discussions and strategy sessions. The discussions that follow from the theme of the talks often provide invaluable material for further research. The strategy sessions in these workshops ranges in topic from grant funding opportunities to water related bills and policies discussed in the state legislature.

Fig. 2. An illustration of the facilitation in the FloridaWCA.
Understanding the diversity of stakeholder groups, their needs and potential contributions to the codevelopment of relevant climate information dominated early workshops (phase 1; see Fig. 2). While many early workshops were held at a central location convenient for statewide participants (e.g., Orlando Utility Commission, Orlando), later meetings were deliberately located throughout the state, reflecting the geographic locales of the participating institutions (Fig. 1), and thereby broadening the focus of the group. This also allowed interaction with local stakeholders who may not have participated otherwise. As a result, the scientists in FloridaWCA were able to focus on different issues and appreciate the wide range of water management challenges that the participants face. The university researchers in the group began to scientifically investigate questions motivated by these stakeholder interactions, leading to peer reviewed publications (e.g., Misra et al. 2012; Bastola et al. 2013; Tian et al. 2014; Misra et al. 2017). Rigorous research on seasonal and long-term projections funded by NOAA projects was underway by some of the members of the FloridaWCA and workshops were central in both development of the research and the sharing of results (phase 3; see Fig. 2). These research topics were presented in subsequent FloridaWCA workshops. The stakeholders who initiated the research also got the first look at the (analysis of the) results of the research, which went through a few more iterations before the researchers submitted an article on it to a peer reviewed journal. The stakeholders began to appreciate the current scientific understanding of the local climate variations and weather phenomenon and the uncertainties associated with them from these presentations. The participants expressed a strong interest in having a central place for information—i.e., a clearinghouse for easy access to information such as presentations at the FloridaWCA workshops and references cited therein including links to any relevant datasets, papers/reports of relevance published by FloridaWCA members. In response, the development of a Knowledge Management System (KMS) subcommittee was formed. The KMS subcommittee subsequently created a website (http://FloridaWCA.org) that incorporated the ideas and the needs of all FloridaWCA members (phase 4; see Fig. 2). Some of the practitioners in the group even started experimenting with the climate information in a test mode to understand the impact on their operations. These were important steps to build trust and confidence that took time and patience. In addition, there were also clear tangible benefits of peer reviewed publications by the researchers and a sense of honor for the stakeholders as the initiators and first witness to cutting-edge new research (phase 4; see Fig. 2).

**Funding model of FloridaWCA.** Stakeholder–scientist partnerships like the FloridaWCA often rise and fall on their project funding. In fact, often the “coordination” and group building aspects that we believe are critical to collaborative research, are the most difficult aspects to fund. FloridaWCA started initially with just the commitment of the members to participate with no financial support. In 2010, simultaneous with the initiation of the FloridaWCA, a proposal was submitted to the Sectoral Applications Research Program (SARP) of the NOAA Climate Program Office. Our hopes were to get a project funded that would support not only the research, but the group building itself. We already had three workshops when we learned that the NOAA SARP funded our first project (NOAA Project 1) in 2011. This was a huge step in providing research support but posed a challenge in community identity and focus. The group’s identity as a partnership was already growing. Now we were entering a stage of focusing on specific project outputs and incorporating specific project planning into workshops. Would group identity continue to grow, or would we fall into similar patterns that narrow focus and participant interests on specific project outputs? This was a dilemma that we faced initially. Our initial identity challenge was defined by whether the group was the NOAA Project or was the NOAA Project part of the group?

NOAA Project 1 had a goal to “improve both the regional relevance and usability of climate and sea level rise data and tools for the specific needs of water suppliers and resource
managers in Florida,” and specifically included funding for the coordination, which was rare. A second NOAA project (2) was funded by SARP in 2012 to improve the regional relevance of seasonal climate forecasts and increase their usability for multiple water managers in Florida to minimize short-term operational risks for water supply as well as ecosystem restoration. It included multiple FloridaWCA stakeholders. Both NOAA Projects 1 and 2 were successfully completed in late 2014. During the development of these projects the group identity amalgamated with the project objectives as the rest of the group not directly involved in the projects began to share their opinions and ideas while also learning from the project. An outcome of this process is that we have an expanded partnership with a principal investigator in the project from Peace River Manasota Regional Water Supply Authority (or Peace River Authority) from the existing membership of the FloridaWCA (Fig. 1) for our recently funded NASA project (funded in 2019). So, in 2020, the group is strong, with new project funding, and once again acknowledging that the group is not just the NASA project but that the new NASA project is a key part of the group.

**Advancement of actionable science in FloridaWCA**

Actionable science, defined as implementing a mode of practice based on the facts gleaned from scientific research, in the context of FloridaWCA refers to the coproduction of information that can support decisions in water resource management. As the FloridaWCA was beginning 10 years ago, relatively little guidance and few tools existed for either water or wastewater utilities to help them prepare for and adapt to the effects of climate change. Although significant attention had been paid to assessing research needs facing the water supply industry (Sankarasubramanian et al. 2009b,a; Brekke et al. 2009; Barnett and Pierce 2009; Stickel et al. 2013; Kiparsky et al. 2014), much of this focus was on the western United States.

FloridaWCA was established in a decade when the state administration was formally instructed to avoid discussion of climate change by the then state governor. In this “lost decade” of denial of climate impacts by the state administration, FloridaWCA served as an informal platform for uninhibited exchange of ideas and concerns of climate impact on freshwater in Florida. The sustained interaction of the FloridaWCA led to useful contributions in participants’ own fields.

The experience of using climate information within Florida water utilities ranged from those already using climate information in hydrologic modeling to those with no experience at all. Early in the collaborative process, stakeholders defined their need for short-term and long-term climate information to help improve water resource supply and management planning relevant to operations (3–12 months), permitting (20 years), and capital planning (20–50 years). In addition, participants wanted to understand key climate drivers related to changes in precipitation, temperature and evapotranspiration patterns, and extreme events over Florida. This period allowed us to impress upon the unique aspects of Florida’s climate variations like the objective definitions of the wet season (Misra and DiNapoli 2013), the influence of the neighboring oceans on the seasonal cycle of the hydroclimate of Florida (Misra and Mishra 2016), and the role of land cover and land use change in the local climate of Florida (Misra et al. 2012; Misra and Michael 2013; Misra et al. 2018) while also emphasizing the potential application of seasonal prediction produced from organized national efforts (Misra et al. 2014; Li and Misra 2014; Tian et al. 2014). Through frequent interactions, the FloridaWCA became a fertile ground for ideation and development of relevant applied research questions that were problem–solution focused. Unlike other stakeholder–scientist partnerships that form as needed, are project based, and sunset at project completion, the continued interaction among FloridaWCA participants allowed an appreciation and understanding of each other and the actors’ professions.
How exactly does the ideation process work to spark relevant research ideas from scientists and stakeholders interacting within the FloridaWCA? This is best illustrated from using the example of tropical cyclones and their possible effect on drought that was expressed at a FloridaWCA workshop. A common perception expressed at the workshop was that landfalling tropical cyclones help to mitigate droughts in the southeastern United States, especially in Florida, where the count of landfalling tropical cyclones is among the highest in the nation (Klotzbach 2011). Therefore, one is tempted to conclude that while these cyclones are destructive, they could be playing an important role in replenishing the freshwater resources of Florida in a drought year. Although intuitively it made lot of sense, Misra and Bastola (2015) found that the contribution of the rainfall from landfalling tropical cyclones on the mitigation of monthly drought in the 28 southeastern U.S. watersheds (including five watersheds in Florida) is relatively insignificant. So much so that the hydrological model uncertainty in estimating the drought index over the 28 southeastern U.S. watersheds is far larger than the sensitivity exhibited by the drought index to the inclusion of rain from landfalling tropical cyclones. The conclusions of this study that landfalling tropical cyclones do not necessarily mitigate droughts in the southeastern United States are also justified by the fact that the timing of the landfalling tropical cyclones in relation to overall soil moisture conditions of the watershed very rarely coincides with droughts. The results of this study were highly appreciated in the group.

Similarly, from these FloridaWCA workshops, the climate scientists were able to see how their data could be potentially used to inform water resources management decisions, whereas utility decision makers could understand the use and limitation of the available climate data. As another example, the issue of the impact of land cover and land use on the temperature and rainfall trends over Florida was raised by several partners in the FloridaWCA. Detailed investigations revealed that urban areas and irrigation in the rural areas of Florida have distinct influence on both surface temperature and precipitation trends (Misra et al. 2012; Selman and Misra 2016; Misra et al. 2018). Similarly, the important role of the sea-breeze type thunderstorms influencing the hydrology of Florida was raised in the FloridaWCA workshops. Research into this topic showed that indeed these types of thunderstorms make a significant fraction of the total seasonal rainfall over Florida throughout the year (Bastola and Misra 2013). In addition, the climate change signal in future climate model projections over Florida is strongly manifested in the daily day and night temperature and rainfall contrasts (Selman et al. 2013; Selman and Misra 2015).

The group has engaged in significant rigorous evaluations of climate models and regional downscaling efforts at both the seasonal scale and long-term climate scenarios. Specific projects included assessing models and data and providing climate information at scales requested by and useful to water supply and resource planning stakeholders (e.g., Hwang et al. 2013; Bastola et al. 2013; Bastola and Misra 2014; Tian et al. 2014; Bastola and Misra 2015). Specific coproduction outcomes of the FloridaWCA have included the following: 1) a set of vetted retrospective and future climate scenarios at industry relevant space/time/event scales (Selman et al. 2013; Hwang and Graham 2014; Bhardwaj and Misra 2019); 2) two applications of this climate information in utility planning processes, models and/or decisions support systems (e.g., Chang et al. 2018); 3) evaluation of the ability of global climate model (GCM) retrospective seasonal simulations to reproduce observed climatological behavior at public water supply relevant space–time scales in Florida (e.g., Hwang et al. 2013; Tian et al. 2014); 4) evaluation of the ability of appropriately downscaled GCMs to reproduce observed hydrologic behavior when used to drive hydrologic models (Hwang et al. 2014; Bastola and Misra 2015); 5) development of a new statistical downscaling technique of GCM data for watershed modeling (Hwang and Graham, 2013); and 6) understanding of climate change implications for Florida water resources (e.g., Obeysekera et al. 2017).
An interesting conclusion that the group was able to draw was that seasonal climate prediction in the winter and spring seasons were more important and useful than in the summer and fall seasons for decision on water sourcing for utilities in Florida. Given the strong seasonal cycle of rainfall over peninsular Florida (Misra et al. 2017), the rainier summer and fall seasons provide sufficient freshwater for supply and storage that is strained in the drier winter and spring seasons. Historically, when the winter seasonal climate is unusually dry (e.g., during some La Niña winters) then the utilities and whole sale water suppliers find it challenging in the following spring season, especially if the dry winter seasonal anomaly was unanticipated as it could lead to expensive remediations. While the seasonal prediction over Florida from climate models have very poor fidelity in the summer (Stefanova et al. 2012; Tian et al. 2014), in the winter the models exhibit more reliable seasonal prediction skills on account of the influence of El Niño–Southern Oscillation (ENSO; Nag et al. 2014; Bastola and Misra 2015). However, scale mismatch between the spatial resolution of the seasonal forecasts and the scale of application for the utilities is still an issue, which is exemplified in the following section.

Stakeholder benefits from FloridaWCA
The decade-long interactions within FloridaWCA very clearly revealed the intersection of our interests in this diverse group. The stakeholders in FloridaWCA indicated that the largest influences on urban water demand and supply in Florida stem from the following sources in approximately the following order:

1) change in policies that directly (e.g., water pricing, water use restrictions, water use efficient fixtures) or indirectly (e.g., urban development plans, industry/agriculture expansion or shrinkage, energy use policies) affect water consumption and supply;
2) large changes in economy like the 2008 financial crisis;
3) changes in demography; and
4) climate variations and change.

The interest to learn about climate science in FloridaWCA was very interesting, despite its lowest influential role in the supply and demand of the urban water in Florida. The stakeholders felt that the scientific basis for the prediction/projection of climate was on a stronger footing than the basis for predicting human behavior that strongly influenced the other three factors. Some stakeholders like the Tampa Bay Water had a strong commitment for environmental stewardship that further motivated them to be part of the FloridaWCA.

Tampa Bay Water and the Peace River Authority, who are water wholesalers in central Florida and both members of FloridaWCA, illustrate the workings of actionable science from a stakeholder’s perspective. The two water wholesalers are quite different in terms of their size, water supply sources, and forecast needs. Tampa Bay Water, the largest wholesale water supplier in the region, provides municipal water to over two and half million customers in three counties in west-central Florida including the cities of St. Petersburg, New Port Richey, and Tampa. The Peace River Authority is a wholesale water supply entity serving four counties in southwest Florida with an estimated population of 300,000.

Example I: Tampa Bay Water. Tampa Bay Water rotates supply among multiple groundwater wellfields, direct river withdrawals from the Hillsborough and Alafia Rivers, an offline reservoir, and desalinated water from Tampa Bay. Their goal in rotating between different water sources is to minimize the impact of groundwater withdrawals (regulated by a permitted limit) on wetlands and lakes in the region that led to a remarkable recovery in lake and wetland water levels (Fig. 3). Tampa Bay Water uses seasonal source allocation models to identify the mix of supply sources, given forecasted seasonal demand and an annual allocation of supply
sources that are tied to the fiscal year budget. Knowing the mix of available supply-source type ahead of time is an important decision variable that dictates, for example, whether to use more expensive desalinated water or cheaper surface water while satisfying both environmental and financial goals. Once an annual budget is allocated, the main objective of the seasonal allocation decision support tool is to stay within the projected annual budget while honoring environmental constraints (the groundwater withdrawal permit) and meeting the seasonally varying demand that is partially driven by actual weather conditions.

A seasonal rainfall-runoff model, which is part of the source allocation tool used by Tampa Bay Water, currently uses Climate Prediction Center (CPC) ENSO seasonal climate outlooks to initialize statistical rainfall models (Asefa et al. 2014). While these models display reasonable skill in the winter and spring seasons over Florida (Stefanova et al. 2012; Tian et al. 2014; Bastola and Misra 2015), Tampa Bay Water finds the seasonal climate forecasts for summer and fall seasons are unreliable. Furthermore, Tampa Bay Water finds that predicting the seasonal hydroclimatic transitions especially from the dry to the wet season and vice versa remain the most challenging aspects of the current operational models. Tampa Bay Water greatly values improvement in seasonal climate forecasts that will help them to bracket the uncertainties in surface water supply availability. This is one of the objectives of the current NASA grant. Similarly, Tampa Bay Water’s water permitting and capital planning decisions have benefitted from the downscaled twenty-first century GCM projections for hydrological simulations for the watersheds of the Hillsborough and Alafia Rivers (Hwang and Graham 2013, 2014).

Example II: Peace River Authority. The Peace River Authority’s primary supply source as their name implies, is the Peace River. It has highly seasonal flows and flows freely to tide without any in-stream dams or salinity barriers. The river is generally unavailable as a supply source for up to 6 months each year. To compensate for this, the agency harvests water from the river in the wet season when flows are high to sustain the utility during low flow periods. Raw water is stored in off-stream reservoirs (Fig. 4a) and also finished water is stored deep underground in aquifer storage and recovery (ASR) wells (Fig. 4b). The agency’s 21 ASR wells make it the largest potable water ASR system in the United States east of the Mississippi River. The water stored in ASR wells by the Peace River Authority is critical to system sustainability. But withdrawals from ASR reserves must be carefully managed. Water stored
in the ASR system mixes with native groundwater and upon withdrawal it has increased levels of hardness, alkalinity, and levels of various other naturally occurring inorganic constituents. If ASR water is withdrawn too fast or if the decision to withdraw is made too soon, the overall blended water quality deteriorates because of these added constituents. Conversely, if too little ASR water is withdrawn or ASR water is withdrawn too late, it increases the risk of a water supply shortage and can exacerbate water quality variance. Thus, ASR system operational decisions require careful consideration, which involves a deliberative process using decision support tools.

A NOAA grant (Project 1), which helped coalesce the formation of the FloridaWCA, also resulted in the development of the Authority’s ASR initiation index in the summer of 2013 (https://toolkit.climate.gov/tool/asr-recovery-initiation-index). This index employs 10 variables: 4 operational variables, 2 hydrologic condition variables, and 4 climate forecast products (Table 1). Each variable is given a weight based upon its typical range in context of the risk posed to water supply. The variables differ in importance and the respective weights reflect this. The index is recalculated weekly by Authority staff as a guide in making the decision on when to initiate ASR operations. A weakness in the current index is that CPC outlooks are offered in a generalized form (i.e., above, normal, below, and equal chances), so they lack specificity with regard to how acute the prediction is. In addition, areas of varying probability in these types of macro forecasts are rarely, geographically well-centered on the Peace River Authority’s area of interest and so site-specific interpolation is often required. As a result of these weaknesses, these variables are not given as great a weight in the index as they might otherwise. The value of this decision tool could, however, be enhanced by replacing the current climate forecast products of the CPC with products that can be updated at a higher frequency, with better quantification, and with increased geographic region specificity, which is being worked on under the NASA grant.

**Discussion and conclusions**

Bringing together multiple stakeholders with different perspectives and organizational contexts can be effective way to build partnerships. But such efforts require engagement, program and logistical coordination, and mechanisms for feedback and sustained support. Encounters must be more than a collection of meetings. What we are interested in, who we are, and what we do together are all equal aspects of building a true stakeholder–scientist partnership.
Florida’s unique water resource management challenges have fostered the development of cross sector partnerships focused on enhancing opportunities for collaborative engagement and dialog even when the political climate was discouraging at best. Such cross-sector partnerships are formed to address societal issues and provide the means for collaboration among business, government, and civil society. These loosely structured organizations typically engage in knowledge transfer activities that bring scientists and practitioners together and provide opportunities to enhance communication, engagement, and multidisciplinary collaboration. This “two-way” model of scientist/stakeholder interaction can be a more effective way of transferring knowledge than the traditional linear, one-way process of disseminating research findings to target groups with the goal of exerting influence on decision-making/adoption behavior (Jacobs 2002; Cash et al. 2006; Dilling and Lemos 2011; Beier et al. 2017; Vogel et al. 2017).

In the case of FloridaWCA, this collaboration went beyond the standard translational engagement activities of presenting research findings to stakeholders. To the institutions involved in FloridaWCA it was providing active support and facilitation of the formation and maintenance of a cross-sector partnership of scientists and practitioners. This has achieved meaningful impacts which has sustained FloridaWCA despite no regular funding for almost a decade. In fact, the FloridaWCA activities met all the coproduction indicators suggested in Wall et al. (2017). For example, the scientists in the group have fostered new scientific pursuits from their interactions with the stakeholders in the group and produced several peer reviewed publications (output indicators of coproduction in Wall et al. 2017). Likewise, the practitioners have benefited in triggering these untapped research avenues and have as a result benefited from improved understanding of the physical processes in the local climate variations (outcome indicators in Wall et al. 2017). The interactions in FloridaWCA have led to some significant changes in the operational practices of some utilities, like the operation of the ASR wells is now informed by the CPC seasonal forecasts in the case of Peace River Authority. Similarly, there is a better appreciation of the environmental stewardship by Tampa Bay Water from the studies conducted by FloridaWCA, which show the impact of land cover and land use change on local climate (i.e., impact indicators in Wall et al. 2017).

One of the key takeaways from this experience is that the careful design of such engagement can strengthen adaptive capacity of organizations in terms of working together to achieve goals and provide mutual benefits to members (e.g., Lemos and Morehouse 2005; Cash et al. 2006; ACCCNRS 2015). However, Lövbrand (2011) cautions that sometimes coproduction stifles...
innovation and forces a response to restricted policies and limited interpretations of useful knowledge. Indeed, from our experience in FloridaWCA we find that the process of coproduction is slow but gratifying. FloridaWCA benefited by meeting regularly throughout the year, which allowed discussion topics to linger till completion or a target of the discussion was achieved. Currently, the FloridaWCA is challenging itself to explore the broader social, policy, and communication issues involved with planning and ultimate implementation of climate adaptation approaches, methods, and tools. The FloridaWCA workshops and collaborative efforts have helped shape the development and implementation of science-based climate information for operational and longer-term water resource planning and management decisions. The value of organizations such as the FloridaWCA as an example of how stakeholder–scientist partnerships may inform infrastructure in a changing world was highlighted by the recent National Climate Assessment reports (USGCRP 2018). FloridaWCA members hope to expand the network’s shared learning, access to resources, and potential for defining further research of specific interest to the stakeholders throughout the southeast United States and beyond.

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