Regional Climate Response Collaboratives

Multi-Institutional Support for Climate Resilience

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Climate variability and change affect society across numerous sectors at multiple spatiotemporal scales. New demands for information and decision support tools to enhance climate resilience at regional scales have prompted diverse agency investments over the past decade (2010s). Here, we discuss lessons learned from a regional climate response collaborative composed of three different climate-service entities and using a multi-institutional approach. These entities have defined roles and responsibilities in terms of the agency missions and expectations, the landscapes they work in, and their stakeholders, but are also linked together by common elements such as climate information needs, shared water resources, and intersecting socioeconomic systems. We can now draw on agencies' experiences to understand how best to leverage existing research, infrastructure, and capacity (personnel and resources) to maximize effectiveness while avoiding redundancy.

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DOI:10.1175/BAMS-D-17-0183.1

No single entity has the exclusive mandate or resources to deliver climate services [for more background see NRC (2009)]. Instead, the institutional capacity for understanding climate variability, stakeholder needs, experimental tool development, technology transfer, and options for adaptation to climate variability and change has been built by many entities over the years. A thorough discussion of the myriad of entities' contributions to regional capacity building over the preceding years is beyond the scope of this paper. However, some example organizations include the regional climate centers (RCCs), state climate offices, National Oceanic and Atmospheric Administration (NOAA) regional climate services directors, National Drought Mitigation Center (NDMC), and Landscape Conservation Cooperatives (LCCs). (An acronym list can be found in Table 1.) The National Integrated Drought Information System (NIDIS) is a relative newcomer to the space, but has brought new capacity and resources for regional drought early warning systems (DEWs). Dilling et al. (2015) provide further analysis of how decision support capacity intersects with regional climate-related needs.

Our focus here is on a collaboration among entities located within the Rocky Mountain west and northern plains region, which have been supported by the Department of Commerce through NOAA, the Department of the Interior (DOI), and the

U.S. Department of Agriculture (USDA). NOAA established the first university-based Regional Integrated Sciences and Assessments (RISA) program in the United States in 1995; its mission is to "help expand and build the nation's capacity to prepare for and adapt to climate variability and change." RISAs work across a variety of contexts and focus on enhancing the use of science in decision-making and building resilience to extreme events in urban and rural areas, such as drought and coastal flooding. The DOI followed suit in 2009, establishing regionally focused climate science centers (CSCs)[1] through Secretarial Order 3289. CSCs are tasked with providing robust climate science to support DOI agencies (National Park Service, U.S. Fish and Wildlife Service, Bureau of Land Management, Bureau of Reclamation, Bureau of Indian Affairs) that manage departmental land, water, fish, wildlife, and cultural heritage resources. CSCs also work closely with DOI LCCs and state fish and wildlife agencies. Then, in 2014, the USDA organized 10 climate hubs (CH) to develop and deliver science-based, region-specific information and technologies to farmers, ranchers, and foresters that enable climate-smart decision-making. The Hubs' work includes directing constituents to USDA programs that may provide technical and financial assistance. Taken together, there are 26 different RISA, CSC, and CH entities across the United States, each with a unique geographic purview.

Table 1. Acronyms used in text.

Acronym	Entity
ARS	Agricultural Research Service (USDA)
CH	Climate hub (USDA)
CSC	Climate science center (DOI)
DEWS	Drought early warning system (NIDIS)
DOI	Department of the Interior (DOI)
EDDI	Evaporative demand drought indicator
LCC	Landscape Conservation Cooperatives (DOI)
NCCSC	North Central Climate Science Center (DOI)
NDMC	National Drought Mitigation Center
NIDIS	National Integrated Drought Information System (NOAA)
NOAA	National Oceanic and Atmospheric Administration
NPCH	Northern Plains Climate Hub (USDA)
PRF	Pasture, rangeland, forage
RCC	Regional climate center (NOAA)
RISA	Regional Integrated Sciences and Assessments (NOAA)
RMA	Risk Management Agency (USDA)
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey (DOI)
WRIR	Wind River Indian Reservation (used for Drought and Climate Outlook Summary)
WRR	Wind River Reservation
WWA	Western Water Assessment (RISA)

This paper highlights a regional climate response collaborative located in the Rocky Mountain west and northern plains that comprises three entities: Western Water Assessment (WWA), North Central Climate Science Center (NCCSC), and Northern Plains Climate Hub (NPCH). For 19 years, NOAA has supported WWA, a RISA program based at the University of Colorado Boulder covering a three-state region.[2] WWA is primarily a research unit that focuses on how to make climate information more usable at regional scales. With strengths in hydrology, climate science, and decision science, WWA has strong ties with water resource managers.

The NCCSC opened its doors in 2011 to serve DOI land managers within a seven-state region.[3] As a university–agency partnership,[4] similar to WWA, the NCCSC leverages academic research and extensive U.S. Geological Survey (USGS) capabilities to bring the best climate science to federal land managers,

[1] During the preparation and review of this article, congressional action resulted in a name change for one of the institutions discussed here: Climate Science Centers (CSCs) will in the future be known as Climate Adaptation Science Centers. This name change went into effect just as we went to press, so we have used the old name in the body of the article.

[2] Colorado, Utah, and Wyoming

[3] North Dakota, South Dakota, Nebraska, Kansas, Colorado, Wyoming, and Montana

[4] Hosted by Colorado State University in collaboration with eight additional universities in the region at the time this paper was written.

state wildlife agencies, and tribal resource managers. NCCSC also provides opportunities for university and USGS researchers to engage with decision-makers.

The USDA NPCH was established in 2014 to provide weather- and climate-related information and decision support tools to farmers, ranchers, forest landowners, and tribes striving to adapt to climate variability in a six-state region.[5] NPCH also serves as a messenger in collaboration with the land grant Cooperative Extension for working-land managers, relaying their weather or climate-related concerns and ideas back to USDA, WWA, NCCSC, and other partners.

These three entities' geographic regions do not overlap perfectly with each other, so the examples presented here focus on collaborative projects where geographic overlap does occur, primarily in northern Colorado and Wyoming. Successful collaborative efforts in this region include the following, each led by one of the regional entities with contributions from the others: producing the Colorado Climate Report (Lukas et al. 2014), which was incorporated into the Colorado State Water Plan (www.colorado.gov/cowaterplan); defining the ecological impacts of drought (North Central Climate Science Center 2015); capacity-building and coproduction of drought preparedness tools with tribes in the Wind River Indian Reservation (North Central Climate Science Center 2016), including early application of a new drought indicator, the evaporative demand drought indicator (EDDI) (Rangwala et al. 2015); development of the Drought, Ranching, and Insurance Response Model to inform decision-making in the region's extensive rangeland livestock industry (Western Water Assessment 2017); and an assessment of the vulnerability of grazing and confined livestock to mid- and late-twenty-first century climatic predictions (Derner et al. 2018). Next, we describe two of these examples in greater detail to illustrate how the collaborating entities' expertise and resources are typically leveraged to serve stakeholders' needs more effectively and efficiently.

The goal of the Wind River Drought Preparedness Project is to coproduce actionable science for drought preparedness through foundational partnerships with the Eastern Shoshone and Northern Arapaho tribes at Wind River Reservation (WRR), NCCSC, WWA, NPCH, among many other government agencies and university partners. The NCCSC established initial relationships with tribal water resource managers to codevelop the project with the National Drought Mitigation Center and NIDIS, and led initial studies of drought impacts and responses in the region (McNeeley and Beeton 2017). Partnerships among the High Plains Regional Climate Center, NDMC, NIDIS, and NCCSC have enabled the coproduction of quarterly drought and climate summaries for WRR and the surrounding area (Wind River Indian Reservation Drought and Climate Summary). The partnership with WWA is supporting the testing of innovative drought tools such as the EDDI for the WRR (Hobbins et al. 2016), and providing an overall evaluation of the project. The summaries and EDDI together provide the infrastructure for monitoring and early warning systems, and support decision-making on the ground. All partners are working together to synthesize this information into an integrated social–climate–ecological vulnerability assessment that will provide the science needed to develop a reservation-wide drought management plan, while the NPCH is working specifically to integrate climate information into agricultural and ranching sections of the WRR Agricultural Resources Management Plan.

A second example, the Drought, Ranching, and Insurance Response Model collaborative effort, was motivated by widespread drought in 2012 (Hoerling et al. 2014), which had major impacts on the region's rangelands and triggered large reductions in cattle herd numbers due to reduced forage availability and high feed prices. In response, USDA's Agricultural Research Service (ARS) developed an online drought calculator to help ranchers assess forage availability (Dunn et al. 2013). USDA's Risk Management Agency (RMA) also rolled out a pilot pasture, rangeland, forage (PRF) insurance policy for livestock producers, indexed to NOAA's gridded precipitation product (USDA Risk Management Agency 2015). WWA brought these two USDA offerings together in an integrated computer simulation model to inform livestock producers' adaptation decisions in the face of drought (Derner and Augustine 2016). WWA's model features a drought forage calculator based on local conditions, the cost and expected profit of different drought adaptations (e.g., purchasing supplemental feed versus early marketing), and a PRF insurance calculator based on a producer's specific rainfall grid. WWA worked closely with NPCH to improve the model's representation of livestock production decisions and define the range

[5] North Dakota, South Dakota, Nebraska, Colorado, Wyoming, and Montana

Table 2. Characteristics of the federally supported Regional Climate Response Collaborative in the northern plains and Rocky Mountain west.

	Western Water Assessment	North Central Climate Science Center	Northern Plains Climate Hub
Supporting agency and program	National Oceanic and Atmospheric Administration (NOAA)	Department of the Interior (DOI), U.S. Geological Survey	U.S. Department of Agriculture (USDA)
Primary users, stakeholders, constituents	Federal, municipal, regional, residential; water resource managers	Department of the Interior, state land managers, and tribal environmental professionals	Agricultural and natural resource managers; ranchers, farmers, forest land owners
Sectoral focus	Water resources, urban, hazards, science policy	Wildlife, wildland, tribal	Agriculture and forestry
Annual direct agency support (U.S. dollars)	$700,000	$2,000,000	$475,000
Start year	1999	2011	2014
Mission	To conduct innovative research and engagement aimed at effectively and efficiently incorporating knowledge into decision-making in order to advance the ability of regional and national entities to manage climate impacts.	To provide the best possible climate science to DOI land managers and provide university and USGS researchers an opportunity to work with an engaged and proactive applied management community.	To develop and deliver science-based, region-specific information and technologies that enable agricultural and natural resource managers to make climate-informed decisions, and to provide access to assistance for implementing those decisions.
Geographic focus	UT, WY, CO	Upper Missouri River basin (MT, ND, WY, NE, SD, CO, KS)	Northern plains (ND, SD, NE, MT, WY, CO)
Temporal focus	Seasonal to 2100	DOI and tribal management planning horizons	Working-lands management planning horizons (days to decades)
Research to application mode	Research focus informed by needs of decision-makers	Research and applied	Some applied research; greater emphasis on transfer of information and tools to end users
Research to application process	Coproduction using interdisciplinary research teams	Foundational science with client requirements	Direct working land managers to tools and USDA programs that may provide technical and financial assistance to reduce risk and increase resilience
Operations and staff	University director; program manager; two regional engagement experts	USGS director and university director; USGS staff; university researchers	USDA ARS director, fellow, and liaison; university coordinator; support of FS and NRCS staff
Federal–university partnership	Single university with NOAA/ESRL	University consortium (nine) with USGS's National Climate Change Wildlife Science Center (NCCWSC)	USDA collaborations with Cooperative Extension and Agricultural Experiment Stations at land grant universities (six)

Table 2. Continued

	Western Water Assessment	North Central Climate Science Center	Northern Plains Climate Hub
Funding model	Through NOAA/OAR	Through USGS NCCWSC	Through six USDA agencies
Stakeholder advisory committee	Eight members from academia, federal agencies, nonprofit sectors	Federal employees and Tribal representative, run jointly with the NPCH	Federal employees and Tribal representative, run jointly with the NCCSC
Core scientific strengths	Hydrology, climate modeling, paleoclimate, decision science, evaluation, usable science	Ecosystems and ecological modeling, remote sensing, public and tribal lands, decision support	Agricultural production, soil and crop science, rangelands, systems modeling, adaptation strategies, management practices, social sciences

of drought management options available within it. NPCH has also arranged for livestock industry experts to meet with WWA to discuss, test, and improve the model. At the time of this writing, both online and downloadable versions of the model are available online from WWA, and it is being applied in a variety of user experiments to test hypotheses about the role of insurance and enhanced information in drought risk management.

LESSONS LEARNED. Many factors have contributed to the successful transdisciplinary efforts and outcomes of this regional climate response collaborative. We look forward to further refinements of on-going efforts to achieve efficient and effective working relationships at a regional level to build climate resilience with targeted resources.

Lesson 1. Collaborative success of our three regional climate entities was manifest in recognizing, appreciating, and leveraging differences and synergies across regional partners (Table 2). Collectively, the three regional climate entities embrace a shared focus to address stakeholder-driven priorities with our staff's combined skills, knowledges, and experiences in scientific, technical, and information transfer.

Lesson 2. Emphasizing transdisciplinary services facilitates cross-agency/department collaboration through regional nodes involving direct connections to each climate entity. Services offered, for example, through the USDA-supported NPCH or the Wind River Project benefit from their close collaboration with the NOAA-supported WWA's research on seasonal drought forecasting and decision-making. These stakeholder-focused collaborations enable interdisciplinary and multi-institutional efforts at regional scales, which propel science-based information into entirely new decision spheres. For example, NPCH has longstanding relationships with farmers and ranchers through USDA service centers, agricultural experiment stations, and cooperative extension at land grant universities and producer organizations; NCCSC has close ties with state and federal fish, wildlife, and resource managers as well as tribal communities; and WWA works hand-in-hand with water resources managers and municipalities.

Lesson 3. Ongoing active communications resulting from intentionally created integrated management structures fosters the building of relationships and synergistic leveraging. For example, the NCCSC and NPCH share a joint stakeholder committee; members of the WWA research team are imbedded within NCCSC's management structure; the WWA Advisory Board includes leadership from NCCSC and NPCH; and the three entities hold twice-yearly joint meetings. Regular maintenance and nurturing of these connections between nodes, or "webs of connectivity," are essential to the practical functioning of our collaborative work and thus our success in serving the needs of stakeholders (Vogel et al. 2007, as cited in Dilling et al. 2015).

Lesson 4. The successful collaboration benefitted from early agreement on a set of common principles for delivering climate services at a regional scale (described further below). Common principles can also provide guidance for other regional collaboratives that may emerge in the future from other federal agencies.

COMMON PRINCIPLES. All three organizations share a common principle of aiming to codevelop and coproduce science with stakeholders to support climate-smart decision-making (Lemos and Morehouse 2005). Research and outreach agendas are therefore carefully designed to optimize their relevance to stakeholder-driven priorities. Outcomes focus on an ongoing process of action and adjustment, or adaptive management, rather than prescriptive solutions, with active engagement of stakeholders throughout the entire effort.

Each entity strives to remain flexible and responsive to their primary stakeholders, and cognizant of the emerging or evolving regional challenges posed by extreme climate events. This flexibility is made possible by an adaptive management structure, where investments and divestments can be made quickly, and decisions about realignments can be made strategically within the organizations themselves. An example of this flexibility is an ad hoc webinar that our collaborative organized at the onset of the El Niño signal in 2015. Scientists from WWA presented material while the NCCSC and NPCH engaged their unique sets of stakeholders for participation. The webinar resulted in a front-page article in the *Wyoming Livestock Roundup* newspaper (a stakeholder of the NPCH; Albert 2015), and provided insights about ecological impacts, which NCCSC contributed to NOAA's Missouri River basin region El Niño Impacts and Outlook report (NOAA 2015).

Scientists within each entity also share a commitment to successful collaborations across disciplines and institutions, and a dedication to engage with stakeholders and decision-makers across sociopolitical divides. Members of the collaborative discuss scientific and organizational failures, and share lessons learned so others can avoid similar pitfalls. Communication skills are valued alongside scientific excellence. Researchers often put these communication skills to use as "climate counselors," working with stakeholders to synthesize and tailor climate science information to most effectively address questions at hand. This requires an emphasis on listening and communicating early, often, and iteratively. Perhaps most importantly, collaborative team members understand the context of climate in the scope of regional priorities and concerns because effective solutions must reflect the missions of individual entities as well as the realities of our diverse stakeholder communities (Table 2).

All three entities endeavor to foster mutual engagement, knowledge, and trust with "on-the-ground" stakeholders and decision-makers that require sustained commitment beyond two- or three-year research projects. This necessitates a different funding model and expectations for practical, two-way translation of science for effective transfer of knowledge and learning, and feedback loops for iterative collaborations. This regional climate response collaborative, through diversity of scientific and support staff with long-term partners, facilitates more rapid and relevant dissemination of usable science from collaborative efforts, through the most appropriate partner for a particular project, rather than having to forge new relationships for each new decision support project.

TRANSFERABILITY TO OTHER REGIONS. Regions differ and have unique sets of leaders, sensitivities, and decision contexts on the ground. Nonetheless, in addition to the lessons and principles discussed above, we offer some additional thoughts specifically focused on collaboration from our own experiences that may transcend regional differences and help others interested in launching regional climate response collaboratives.

First, it is important that entities place a conscious, deliberate focus on making collaboration successful for each entity as well as the larger collaborative. Collaboration across agencies requires staff time, targeted financial resources (to support meetings and projects), and prioritization among many competing demands. For example, the three centers' periodic retreats require management focus and funding, and since the three centers rotate responsibility for these meetings, all have "skin in the game" for their success.

Second, it helps to have some existing collaborations at a smaller scale upon which to build a more permanent and routine expectation of institutional collaboration. For example, individual scientists in our organizations already had experiences working together on prior research projects, which created an existing reservoir of trust and common ground upon which to build. If such projects do not yet exist in a region, focusing on one or two small, naturally arising project opportunities (e.g., collaborative pilot projects) is recommended prior to building a bigger regional collaborative.

Third, it is important to discuss and debate up front the reasons for collaborating and whether there is added value for each organization. As previously described, we had a natural division of roles and responsibilities in terms of the types of landscapes we worked in, the stakeholders we interacted with, and the expectations of each of our agencies. Nonetheless, our landscapes and stakeholders are also linked together by common elements such as climate information needs, the geographies of shared water resources, and intertwined socioeconomic systems (such as grazing activities that take place both on private and public lands). Discussing and determining the real value added for collaboration produces a strong foundation for underpinning commitment to the process.

ADDRESSING POSSIBLE BARRIERS TO COLLABORATION. Naturally, there are barriers to embarking on a regional climate response collaborative. The degree of interorganizational interactions implied here requires significant management time and attention—a scarce resource. Time demands are often cited as key barriers, and sustained management commitment to strategies like regularly scheduled meetings are needed to ensure these efforts get their due. In addition, it is important to seek out opportunities that provide a "win" for individual entities as well as for the whole—by ensuring that the collaboration activity supports existing goals that each agency must accomplish as well as the larger goal of the regional project.

Second, because the three entities are pioneering new approaches, personnel transitions have the potential to derail forward motion. All three entities will inevitably struggle with the balance between reliance upon innovative leadership and regularizing processes to institutionalize the new ways of operating. In our case, personnel transitions have already happened in all three of our organizations, but the collaborative effort remains steadfast and new projects are being coproduced, a clear sign that the collaboration has become institutionalized.

Third, like any other collaboration across disciplinary lines, language can be a barrier, such as the use of different terminology and vernacular in different sectors. For example, most ecologists are not familiar with "cow-calf operations," and many agriculture specialists do not track "evolutionary adaptive capacity." We emphasize joint retreats every six months in a casual setting that enable dialogue and presentations designed to be accessible rather than "impressive." Language barriers can be persistent, and attention needs to be focused on making sure that true understanding has taken place, which can be time consuming.

Finally, "agency turf" can derail attempts at collaboration. In the climate services landscape, however, there are many stakeholder needs in different contexts across multiple spatiotemporal scales; thus, many opportunities arise to be creative and unique in providing usable science. Our experiences are that keenly focusing on opportunities and clearly articulating differentiated missions of organizations can mitigate turf battles.

CONCLUSIONS. Developing new ways of connecting, leveraging, and supporting regional climate response collaboratives shows promise in building and improving regional climate resilience. It is our experience that collaboration itself is a form of adaptive capacity that enhances efficient coproduction and delivery of relevant information through existing networks of trusted relationships. Establishing and maintaining a diversity of partners ensures that redundancy is minimized and enables flexibilities in response to emerging stakeholder and societal priorities. Further experimentation with regional strategies for collaboration, coproduction, and interdisciplinary communication is needed to continue to strengthen climate resilience.

ACKNOWLEDGMENTS. The authors appreciate support from the DOI climate science centers, the USDA climate hubs, the Cooperative Institute for Research in Environmental Sciences, the NOAA/ESRL Physical Sciences Division, and a grant from the NOAA Regional Integrated Sciences and Assessments Program to the Western Water Assessment (NA10OAR4310214). Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. government.

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