University of Colorado-Boulder Hosted
North Central Climate Adaptation Science Center
Year 3 Annual Report

July 2021

Submitted by: Jennifer Balch (University Director)

North Central
Climate Adaptation
Science Center

1. TERM SHEET
The Term Sheet of key elements of the USGS-University of Colorado (CU) Boulder Cooperative Agreement for the hosting of the North Central Climate Adaptation Science Center (NC CASC) is located in **APPENDIX I**.

2. ADMINISTRATIVE
Award Recipient: Dr. Jennifer Balch
Issued to: The Regents of the University of Colorado
Attn: Lori LaFon
3100 MARINE ST STE 481 572 UCB
BOULDER CO 80309-0001

Institution of the Award Recipient: University of Colorado-Boulder
Award Agreement Number: G18AC00325
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2. PURPOSE AND OBJECTIVES
In Year 3, the NC CASC and its consortium partners continued to make significant progress towards its core goals: partnerships; science; capacity building; and communications/outreach. The efforts we describe in this report are the result of key partnerships with stakeholders, including the U.S. Fish and Wildlife Service (FWS), National Park Service (NPS) Climate Change Response Program, and Tribal Colleges and Tribal students.

Year 3 science highlights include climate science support for FWS, NPS, Tribes, state wildlife agencies and other partners, including the development of climate summary documents and historical and projected time series data for FWS Region 6 Species Status Assessments. Key consortium partner (CP) activities for Year 3 were the Wildlife Conservation Society (WCS) stakeholder workshops on adaptation and conservation planning with the Wyoming Game & Fish Department and formal evaluation of WCS-funded adaptation projects; University of Montana (UM) work on post-fire regeneration, stakeholder workshops, and continued collaboration with the Northwest CASC's *Deep Dive into Managing Post-Fire Vegetation in a Warming Climate*; Conservation Science Partners (CSP)'s leveraged work on transformational drought and visualizing ecological drought; and South Dakota State University (SDSU) outreach to land managers to understand climate information needs.

A highlight of our Year 3 capacity building activities was the *NC CASC Theory of Change* strategic planning process we engaged in with our USGS and consortium partners. Although this activity was not included in the original proposal, the effort greatly strengthened our internal capacity to meet the climate science needs of stakeholders in the North Central region (see **RESULTS: Capacity Building**).

In Year 3, the NC CASC continued to train the next generation of climate adaptation scientists and practitioners. We played a leadership role in the inaugural cohort of the CASC-network Climate Adaptation Postdoctoral (CAP) fellows program, focused on the *Future of Fire*. We are also coordinating with USGS partners to support a CU PI (Holly Barnard) with developing a North Central region project for the second cohort in the CAP fellows program focused on the *Future of Aquatic Flows*. This year the NC CASC supported four summer graduate research assistants, mentored undergraduate students in the University Corporation for Atmospheric Research - Significant Opportunities in Atmospheric Research and Science (SOARS), and the National Science Foundation funded Earth Data Science Corps (EDSC)

programs. Additionally, our Education Team hosted a remote half-day data-intensive Climate Data 101 in Python Workshop, and will be offering this workshop a second time in September 2021 (see **RESULTS: Capacity Building**).

We expanded our communications/outreach capacity in Year 3. In January 2021, we increased the frequency of the NC CASC Webinar Series to a monthly interval, and continued to share events and successes on our website and in our newsletter. Additional efforts in Year 3 arose in response to CASC-network discussions on program management, diversity and inclusion, and early career training programs. Throughout summer 2021, the NC CASC is actively participating in CASC-network Collaborative Visioning discussions related to future investments in climate adaptation science, information provision and support for adaptation and resilience efforts.

In Year 3, COVID-19 continued to cause significant administrative challenges for the NC CASC. COVID-19-related challenges, e.g., childcare constraints and remote schooling logistics, reduced the amount of time that members of our CU team and consortium were able to devote to NC CASC projects. We had one team member take advantage of the federal CARES Act. Additionally, COVID-related travel restrictions and public health guidelines on social-distancing limited our ability to meet some project deliverables (e.g., in-person meetings, stakeholder engagement, and science summits), as outlined in the award Term Sheet (**APPENDIX I**).

3. ORGANIZATION AND APPROACH

A summary table of funded University of Colorado (CU) personnel is located in **APPENDIX II**. This table also includes the roles, responsibilities and percentage of salary on the award for each individual.

Institutions receiving sub-awards: Conservation Science Partners (CSP): Co-PI Shelley Crausbay; South Dakota State University (SDSU) Extension: Co-PI Laura Edwards; University of Montana (UM): Co-PI Phil Higuera; and Wildlife Conservation Society (WCS): Co-PI Molly Cross. James Rattling Leaf (co-PI) is now conducting activities for the Great Plains Tribal Water Alliance (GPTWA) under the CU hosting agreement.

Contributions from unfunded personnel:

- Christy Miller Hesed (Postdoctoral fellow) is the project coordinator for the *Grasslands Synthesis Project* (see **RESULTS: Science**) that is funded by a USGS CASC directed funding research grant.
- Stefan Tangen (Tribal Resilience Liaison) engages regularly with NC CASC staff through a variety of meetings/activities, including but not limited to bi-monthly NC CASC All Hands Staff meeting, monthly Climate Science Support Platform meetings, monthly NC CASC Stakeholder Engagement meetings, monthly Consortium Partner calls, the Rosebud Sioux Tribe Climate Adaptation Planning efforts (see **RESULTS: Science**), and the NC CASC *Theory of Change* (see **RESULTS: Capacity Building**). This position is funded by the Bureau of Indian Affairs.
- TBD (Communication Specialist) will work with the NC CASC team to develop web content, write feature articles, and update the NC CASC Communication Plan. This 60% position will be supported by a USGS CASC funded research project, *Creating a North Central Regional Invasive Species and Climate Change (NC RISCC) Management Network* (PI R. Chelsea Nagy).

Issues hiring or retaining personnel: Max Joseph departed the NC CASC in March 2021, and as a result, Natasha Stavros and/or a graduate student may require some salary support to oversee the maintenance of the Climate Futures Toolbox (CFT) in the interim. Jenny Palomino departed the NC CASC in June of 2020 and Lauren Herwehe Kim took on the training responsibilities of the NC CASC, in coordination with Leah Wasser.

Summary of consortium governance and operations, and interactions. The role of each consortium partner (CP) is to produce actionable science on a dedicated management theme, serve as a connector between researchers and stakeholders in their region, and help guide the overall efforts of the NC CASC. Supported CP activities are co-determined by the CPs and the CU team (detailed in **RESULTS: Science**), and also include funds to support CP-hosted NC CASC meetings (e.g., annual CP meetings). Support from CU includes: support and consultation on the best-available climate science from the CU Climate Science Support Platform (CSSP); communications/outreach support (see **RESULTS: Communications/Outreach**); and access to additional training and skills-building opportunities. Monthly conference calls with Consortium Partner Co-PIs, monthly CSSP calls, and an annual CP meeting are key touch points for consortium interactions.

4. RESULTS

A selection of key results from Year 3 are summarized under our four core goals: partnerships; science; capacity building; and communications/outreach.

Partnerships: Our ongoing stakeholder tracking efforts illustrate that we continue to work with stakeholders from 99 different organizations or groups, including: 26 Tribal Nations or inter-Tribal organizations (1 new in Year 3); 10 Tribal Colleges; 11 Federal government agencies; 15 state government agencies; 17 academic or research institutions (4 new in Year 3); 18 nonprofit organizations (7 new in Year 3); and 2 regional boundary organizations. The Grasslands Project was responsible for 109 out of 167 stakeholder interactions logged in Year 3, and was a key mechanism for creating new connections and strengthening existing ties. James Rattling Leaf's outreach and engagement activities have been key to building/strengthening partnerships with Tribal organizations and colleges in the North Central region (see **OUTREACH**). Part of Heather Yocum's time (10% FTE) coordinating the *Grasslands Synthesis Project* (see *Grasslands Synthesis Project* in **RESULTS: Science**) is supported by the NC CASC Cooperative Agreement, including her effort to coordinate with and leverage the USDA Northern Plains Climate Hub's efforts to conduct a vulnerability assessment for U.S. Forest Service grasslands. To expand the number and depth of our partnerships, in Year 3 the NC CASC initiated a Stakeholder Engagement Working Group (includes Yocum, Rangwala, Wolken, Travis, Tangen and Miller Hesed). The working group is supporting Heather Yocum's efforts to improve stakeholder tracking and refine our Stakeholder Engagement Strategy.

Science: The monthly Climate Science Support Platform (CSSP) calls (co-led by Imtiaz Rangwala and Jane Wolken) continue to be the primary mechanism to promote in-depth science conversations within the NC CASC consortium on topics that inform and advance science activities in support of stakeholder needs in the North Central region. Topics covered in the Year 3 CSSP calls included the: FWS Species Status Assessment process; development of future ecological response scenarios (e.g., Resist-Accept-Direct (RAD) framework); creation of a North Central regional invasive species and climate change (NCRISCC) management network; wildfire risk; and ecological transformation.

In Year 3, the NC CASC continued to advance the understanding of the impacts of climate change and variability on fish, wildlife, plants, water, land, and people by providing relevant and usable science, data and analytic tools to support sound resource management and adaptation in the North Central region. To improve usability of the Climate Futures Toolbox (CFT), a R-Shiny utility was developed by Prasad Thota (see **RESULTS: Capacity Building**) under the direction of Imtiaz Rangwala. Additionally, the NC CASC developed several open workflows and datasets, and maintained other tools (see **APPENDIX III**).

Primary project climate support for FWS, NPS, and state wildlife agencies included developing climate summary documents and historical and projected time series data for FWS Region 6 Species Status Assessments for DeBeque Phacelia and Colorado Hookless Cactus, Cisco and Isely Milkvetch, and Brandegee's Buckwheat. Along with several partners, the NC CASC (Imtiaz Rangwala, Molly Cross, Laura Edwards, John Guinotte, Brian Miller, Stefan Tangen) led the development of the *Ecosystems and Biodiversity* section of the U.S. Climate Resilience Toolkit Northern Plains regional document (web page in development). The NC CASC (Rattling Leaf, Sr., Rangwala, Edwards) are also collaborating with Robin O'Malley (former USGS NC CASC Director) and Chad McNutt (formerly with NOAA/National Integrated Drought Information System (NIDIS); co-founder Livestock Wx) to support the Rosebud Sioux Tribe Climate Adaptation Planning efforts. The NC CASC is providing historic climate and potential futures data for Rosebud Tribal lands with liaison support from James Rattling Leaf, Sr. and Stefan Tangen. Additional project climate support activities with partners are included in **APPENDIX III**.

In Year 3, Max Joseph's NC CASC funded time supported work in partnership with the Playa Lakes Joint Venture and the Bird Conservancy of the Rockies. This effort resulted in a paper that describes an approach to integrate community science and systematic survey data for species distribution modeling (see Joseph et al. 2021 in **APPENDIX V**). Mentoring time by Joseph also supported undergraduate (Ally Fitts) work on watershed delineation using the StreamStats Python package that Earth Lab developed; this work is still in progress.

The NC CASC is able to reach a diversity of partners and land managers throughout the North Central region through the science activities of our Consortium Partners. CP work continued to be disrupted by COVID-19-related issues, including limited capacity, travel restrictions, and an inability to convene in-person events. In addition to those activities described above (**PURPOSE AND OBJECTIVES**), highlights of our Consortium Partners in Year 3 are summarized below (additional details listed in **APPENDIX IV**):

- Conservation Science Partners (CSP): Shelley Crausbay worked with DOI stakeholders (FWS, NPS, BLM) and USFS and NOAA to craft a research agenda for science to support application of the Resist-Accept-Direct framework and effectively support natural resource management in a non-stationary world. Leveraged work by Crausbay includes research on transformational drought and visualizing ecological drought. Additionally, Crausbay's FY20 USGS CASC funded research project, *Exploring the Past to Plan for the Future: Integrating Indigenous Knowledge and Paleo Perspectives to Inform Climate Change Adaptation* with the Ute Mountain Ute Tribe will help inform the NC CASC's co-production model and best practices for combining western science and Traditional Ecological Knowledges.
- Great Plains Tribal Water Alliance (GPTWA): Throughout Year 3, James Rattling Leaf, Sr. has actively connected with Tribes in the North Central region. See list of presentations and webinars in **APPENDIX V**.
- University of Montana (UM): Phil Higuera and Kim Davis hosted a fire manager workshop (February 3-4, 2021), *Managing Post-fire Vegetation Under Climate Change*. Thirty-three participants from 6 state and federal agencies attended this workshop.
- South Dakota State University (SDSU): Laura Edwards and Sean Kelly performed outreach to land managers to understand climate information needs via small focus groups and one-on-one meetings.
- Wildlife Conservation Society (WCS): Molly Cross hosted stakeholder workshops on adaptation and conservation planning with the Wyoming Game & Fish Department. On July 12-13, 2021 she hosted a virtual meeting, *Measuring Climate Adaptation Outcomes* to share and solicit feedback on results from a recent evaluation of adaptation projects supported by the WCS Climate Adaptation Fund.

The *Future of Fire Project* is funded partially by the NC CASC Host Agreement and the National CASC Climate Adaptation Postdoctoral (CAP) Fellows Program. The project is implemented by Postdoctoral fellow Jilmarie Stephens, with supervision by PI Jennifer Balch, and co-mentors Jane Wolken and Imtiaz Rangwala. The NC CASC-led project aims to determine the future size and number of fires, total burn area, and rates of change among years and across space in the contiguous United States. The goal is to explain changes in these fire variables in relation to climate change and changing housing density, which drives human ignitions and fire suppression efforts (Balch et al. 2017). To predict the future (2020 to 2060) size and number of fires, the fire-climate relationships derived in a spatiotemporal Bayesian statistical model by Joseph et al. (2019) are being applied to climate data output from several global climate models (GCM) under two future climate scenarios. The Multivariate Adaptive Constructed Analogs (MACA) dataset consisting of 20 Coupled Model Intercomparison Project (CMIP5) GCMs will be used to provide daily output of requisite variables for future modeling experiments under RCP4.5 and RCP8.5 scenarios (Abatzoglou & Brown, 2012). This research will inform the National CASC CAP Fellows Program regional-to-national syntheses of climate change impacts on fire regimes, fire management, and fire response effort. Additionally, since Stephens was the first CAP Fellow to join the program, she and Wolken collaborated with the National CASC Fire Leadership Team to inform the agenda for the National Climate-Fire Synthesis Workshop (January 13-15, 2021), and Guidance Document to CAP Fellows (March 2021) for the National CASC *Future of Fire Project*.

The *Grasslands Synthesis Project* is funded by a USGS CASC directed funding research grant, and leverages university CASC supported time for Heather Yocum, Bill Travis and Imtiaz Rangwala. The goal of the *Grasslands Synthesis Project* is to establish a baseline of information to inform NC CASC efforts to provide relevant climate science to grassland resource managers. The project is led by PI Heather Yocum and implemented by Postdoctoral fellow Christine Miller Hesed. Despite the challenges of the pandemic, this project has successfully engaged 38 stakeholders (including representatives from BLM, FWS, NPS, Forest Service, Tribal Nations, state natural resource departments, and NGOs) who are volunteering their time to serve alongside NC CASC researchers on two working groups and an advisory committee. The *Management Priorities Working Group* collected, reviewed, and synthesized grassland management plans and documents from Federal, State, and Tribal agencies and NGOs in the North Central region. They identified the key science questions that, if answered, could help grassland managers be successful in meeting their goals and addressing their challenges in a changing climate. These questions are now being addressed by the *Climate & Ecology Working Group*, who are synthesizing existing science to answer questions and identify areas where more research is needed. The Advisory Committee is consulted periodically by both Working Groups to provide additional input to ensure major management issues or scientific considerations are not overlooked.

Capacity Building: A primary goal of the NC CASC is to build a community of researchers and managers, and foster their leadership in science-based resource management. Year 3 capacity building activities in support of this goal are described in more detail below.

To improve our ability to meet the climate adaptation science needs of resource and cultural managers in the North Central region, the NC CASC utilized the expertise of CIRES Education & Outreach to help facilitate the NC CASC (included participation by CU, USGS, CPs, and Tribal Resilience Liaison) through a *Theory of Change* strategic planning process. A *Theory of Change* is a collaboratively-produced, aspirational plan for an organization to effect long-term, transformative change. Through a series of four workshops (January-April 2021) the NC CASC co-developed a shared vision of what change it wants to effect in the world and a roadmap for how we plan to get there in the next 5- to 10-years. A working group (Aparna Bamzai Dodson: USGS Deputy Director; Alisa Wade: USGS Research Coordinator; Jane

Wolken: CU Program Manager; and Stefan Tangen: Tribal Resilience Liaison) is currently developing a summary document that outlines the *Theory of Change* process, results and next steps (Facilitation was supported through the hosting agreement).

In Year 3, we helped train the next generation of earth and environmental scientists and research managers through a data-intensive remote half-day workshop Climate Data 101 in Python Workshop on October 30, 2020. The event was aimed at federal and state agency employees, members of tribal organizations, university researchers, graduate students, and others who use climate data to understand global environmental change in their work. Participants learned how to use Python to open, subset, and visualize MACAv2 climate data downloaded from the Climate Futures Toolbox in the NetCDF hierarchical data format. There was overwhelming interest in this workshop. We received 114 RSVPs from participants from 23 states and were able to reach 45 people in 15 states. Given this interest, to achieve the broadest reach possible (1) we published all training materials online including lessons and assignments, and (2) the event was taught using the cloud-based programming platform JupyterHub, removing the need for software installation or a powerful machine.

The Tribal Climate Leaders Program (TCLP) provides five fully-funded, 2-year fellowships to Native American graduate students affiliated with one of the 32 federally-recognized tribes in the North Central region. The NC CASC welcomed the first PhD student, Shelby Ross (see additional details below) to the Geography Department in Fall 2019, and four masters degree students matriculated in Fall 2020 to the Environmental Studies Program and Department of Civil, Environmental and Architectural Engineering. This year was particularly challenging for the TCLP fellows due to COVID-19-related restrictions and online learning, which limited the benefits from the additional social, professional, and scholarly support from a variety of on-campus and community resources that the TCLP attempts to foster. One TCLP fellow has withdrawn from the program. Six CU programs provide funding for the TCLP, and we continue to seek funding to expand this program to support additional fellows, including applying for the National CASC CAP Fellows Program to Advance Diversity, Equity, and Inclusion in Climate Science Request for Proposal Ideas. These efforts include participating in conversations with the National CASC and other regional CASCs, and working with other CU researchers to include support for Native American graduate students in grant proposals, with the TCLP providing in-kind programmatic support. Heather Yocum is the current TCLP Program Coordinator.

In Year 3, the NC CASC supported four summer graduate research assistants (May-August 2021) at CU Boulder:

- Sarah Jaffe is a PhD student in the Environmental Studies program. She has managed ecological and human-wildlife conflict research projects across the globe, and is currently studying changing human and natural systems, remote sensing, GIS, and how to make Python code reusable for wildlife and land management. During summer 2021, she is working on the *Grasslands Synthesis Project* on spatial analytics and supporting the creation and dissemination of initial results.
- Phurwa Gurung is a PhD student in Geography. His research explores the political ecology of conservation and caterpillar fungus to examine climate change, indigeneity and state building in the Nepal Himalaya. During summer 2021, Phurwa is working on a literature review on the use of traditional ecological knowledges to understand climate change in the North Central region. This summary will provide insight into how to generate effective climate solutions using both indigenous and western science perspectives and best practices for engaging with Tribes.
- Shelby Ross is a PhD student in Geography and also a participant of our Tribal Climate Leaders Program. Her research is focused on understanding the impacts of climate change on health for the Pine Ridge Indian Reservation in South Dakota through qualitative methods of semi-structured

interviews and survey data. During summer 2021, Shelby is working as a graduate research assistant on the *Grasslands Synthesis Project*. Her summer project includes writing a literature review and summary of Tribal Nations grassland and climate change related goals and challenges.

- Prasad Thota is a new Masters student in Civil Engineering. During summer 2021, he is working to support research and data/tool development for the NC CASC Climate Science Support Platform. His activities include the development of an R-Shiny utility for the Climate Futures Toolbox (CFT) and workflows in R to project different downscaled climate metrics, and research into relating drought and heat related climate extremes to ecological response (e.g., wildfire impact, vegetation productivity).

The NC CASC also mentored five undergraduate students in the UCAR SOARS and nine undergraduate students in the Earth Data Science Corps (EDSC) programs. The students worked on projects that support the NC CASC Strategic Science Agenda and offer potential future opportunities to build out additional efforts related to our science and capacity building core goals. Bill Travis and Imtiaz Rangwala led an NC CASC technical project for six EDSC undergraduate students in summer 2020 (not reported in Year 2), guiding students in creating a Python workflow to understand the impact of climate change on the white-tailed ptarmigan in Rocky Mountain National Park. In summer 2021, they are mentoring five EDSC students on a project using big data and Python to relate ecosystem responses to climate drivers in the Northern Great Plains Grasslands ecosystem. The NC CASC also worked synergistically with CU's Earth Lab to train professional students. In spring and summer 2020, Imtiaz Rangwala and Gabriel Senay led an NC CASC technical project for a student in the Earth Data Analytics - Foundations Professional Graduate Certificate program (not reported in Year 2). The project created a reproducible Python workflow for turning raw soil moisture data into a usable and standardized format for study. Additionally, Rangwala provided statistics mentorship to another professional certificate student researching agricultural production in Australia in summer 2021.

Communications/Outreach: Communications and outreach are embedded in all aspects of the NC CASC's activities, and integrate our co-produced science, partnerships, and capacity building efforts. In support of the capacity building and communications and outreach goals of the NC CASC, Katherine Halama was hired as a part time, regular employee when her temp-aide appointment expired in March 2021 and continues to work with Dawn Umpleby on the activities described below. The total combined funded percentage of effort for the two team members is 90% FTE. The NC CASC is currently advertising for a communications specialist (60% FTE) with a focus on writing and content creation.

We utilize the following strategies to broadly communicate our activities within the NC CASC network: NC CASC Website/Newsletter/Social Media: In Year 3, the NC CASC continued to develop its website by adding several new pages: Climate Science Support Platform (CSSP); Case Studies & Summaries; Webinars; Communications Tools; and Employment Opportunities; and upgrading others. The NC CASC website also hosts a For Tribal Partners page that contains content organized by the Tribal Resilience Liaison (Stefan Tangen), including links to the NC CASC Tribal Engagement Strategy (2019-2024), archived issues of the Tribal Climate Adaptation Newsletter (distributed to 250 subscribers), and videos of the Tribal Climate Webinars (attended by 30-50 participants, including 10 Tribal Nations). We continue to issue a NC CASC Newsletter, currently on a bi-monthly basis and distributed via the website, Facebook (281 followers), Twitter (791 followers), and a Mailchimp email distribution list (689 contacts).

The NC CASC YouTube channel has 99 subscribers. It contains 27 videos to date (from 2018 to present), including 11 Tribal Climate Webinars and 10 NC CASC monthly webinars (see below); the number of total views for all webinars for the period October 2018 to July 12, 2021 is 1,929.

In October 2020, the communications team worked with CIRES IT to set up the NC CASC help ticket system (Spiceworks) with the goal of centralizing the submission of communications content. The implementation of this system has increased efficiency and productivity. For the period October 1, 2020 to July 12, 2021, the team has processed 309 individual help ticket requests, with the majority of tickets requiring multi-part responses. NC CASC news is also distributed through CIRES and CU communications channels.

NC CASC Webinar Series: In Year 3, the frequency of the NC CASC Webinar Series increased from bi-monthly to monthly. The webinars highlight ongoing research from the NC CASC network, as well as feature topics of critical importance to natural resource managers and other stakeholders in the region. Topics for 2021 included revised thinking on adaptation, realizing drought, wildfire and climate change scenarios, changing fire regimes, and Grass-Cast, a grassland productivity forecast to inform rangeland decisions developed by the USDA Northern Plains Climate Hub. Since November 2020, we have had 673 registered participants (495 individuals, 98 who attended more than one webinar; attendance is ~60-75% of registered participants). Registrants came from 19 federal agencies, 12 states, 13 Tribal nations, 47 academic institutions, 24 non-profit organizations, 5 CASCS, and 6 private organizations.

5. OUTREACH

NC CASC researchers produced 24 peer-reviewed publications (includes one *In Press*, and one *In Revision*), technical reports and op-eds in Year 3. Additionally, the NC CASC engaged in several outreach activities, including 18 Tribal focussed presentations/webinars, 10 major stakeholder engagement activities, and 16 media requests (see **APPENDIX V**).

6. NEXT STEPS

The mission of the NC CASC is to generate the science to help resource managers in the North Central region adapt to a changing world. Our Strategic Science Plan (2019-2024), USGS-University of Colorado Boulder Cooperative Agreement (see **APPENDIX I: Term Sheet**), and shared vision (see *Theory of Change* in **RESULTS: Capacity Building**) of our core goals (partnerships, science, capacity building, and communications/outreach) will help guide our Year 4 activities.

Partnerships: Key partnership building activities will include targeted stakeholder engagement. In Year 4, we will continue to build partnerships with researchers and managers around fire, ecological transformation, grasslands management, invasive species, and climate futures. We will continue to strengthen partnerships within the CASC-network through our engagement in cross-CASC meetings (e.g., Network Collaboration Call, Program Manager Call, Communications Call, and Decolonize our Work Group). Further, since COVID-19 inhibited us from hosting the in-person Climate Solutions Summit originally proposed for Year 3, we will explore ways to host a meeting, or several smaller remote engagements, with the purpose of bringing together students, scientists, educators, and stakeholders engaged in NC CASC efforts. We will connect with our colleagues and build off of the successes of our regional CASC partners who have run successful remote meetings in this year, e.g., Northwest Climate Conference.

Science: The NC CASC will continue to actively engage in cross-CASC science activities, including the National CASC CAP Fellows Program for the *Future of Fire* and *Future of Aquatic Flows* postdoctoral cohorts, and the CASC-network Collaborative Visioning discussions and related products. To refine our understanding of climate adaptation science, we plan to conduct a systematic assessment of how climate scenarios have been incorporated into species status assessments, wildlife management plans, and landscape scenarios. Additional key science efforts in Year 4 include: continued climate science

support via several FWS species status assessments, climate information/services to the Rosebud Sioux Tribe, and the development of datasets and workflows (including Shiny App utilities); and outreach products for the *Grasslands Synthesis Project* (e.g., a USGS technical report for each working group, and a peer-reviewed journal article). Consortium Partner activities in Year 4 include CSP research informed by the RAD framework; continued work by UM to develop science and outreach tools to aid in post-fire revegetation; and continued outreach by SDSU to local stakeholders to understand climate science needs. See **APPENDIX IV** for additional details on planned workshops and meetings hosted by our Consortium Partners.

Capacity Building: The NC CASC recognizes the importance of building capacity and increasing diversity, equity, and inclusion in science. We will continue to look for ways (both in- and outside the CASC-network) to expand the Tribal Climate Leaders Program (TCLP) beyond the inaugural cohort. Due to the high interest in the Climate Data 101 in Python Workshop, the NC CASC education team plans to offer this training a second time in September 2021. In Year 4, we also plan to host at least one additional training focused on creating open and reproducible workflows, and working with heterogeneous data formats in support of climate data analysis.

Communications/Outreach: We will continue to expand on our communications/outreach efforts with the website (e.g., interactive webpages for featured projects such as the *Future of Fire* and *Grasslands Synthesis Project*), newsletters, and monthly webinar series. As we transition from Year 3 to Year 4, we will be expanding our NC CASC team to include a part-time Communication Specialist (see also Contributions from unfunded personnel) that will assist the NC CASC with developing web stories and targeted project summary documents (e.g., 2-page topical outreach materials), and refining our communications plan. The Communication Specialist will also increase our capacity to engage in communication activities within the broader CASC-network (e.g., monthly CASC Communications Call).

7. BUDGET

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8. LITERATURE CITED

- Balch, J.K., Bradley, B.A., Abatzoglou, J.T., Nagy, R.C., Fusco, E., and Mahood, A. 2017. Human-started fires expand the fire niche across the U.S. (1992-2012). *Proceedings of the National Academies of Science*, 114(11):2946-2951.
- Joseph, M.B., Rossi, M.W., Mietkiewicz, N.P., Mahood, A.L., Cattau, M.E., St. Denis, L.A., Nagy, R.C., Iglesias, V., Abatzoglou, J.T., and Balch, J.K. 2019. Spatiotemporal prediction of wildfire size extremes with Bayesian finite sample maxima. *Ecological Applications*, 29(6):e01898.
- Abatzoglou, J.T. and Brown, T.J. 2012. A comparison of statistical downscaling methods suited for wildfire applications. *International Journal of Climatology*, 32:772-780.

APPENDIX I--Term Sheet

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APPENDIX II: Funded University of Colorado (CU) personnel

Funded University of Colorado (CU) personnel; GPTWA=Great Plains Tribal Water Alliance; NCASC=National CASC. YR3=Budget Year 3 funds; and YR2=Budget Year 2 funds carried forward to Year 3.

Person	Role	Responsibility	Actual Level of Effort (10/1/20-9/30/21)
Jennifer Balch	University Director	Responsible for coordinating all elements of the cooperative agreement, including the leadership and CU teams. Supervises Jilmarie Stephens.	
Jane Wolken	Program Manager	Oversees day-to-day university operations of the NC CASC. Engages in cross-CASC activities, including the Fire Leadership Team, and Program Manager and Network Collaboration meetings. Co-mentors Jilmarie Stephens, and Phurwa Gurung.	
Lisa Dilling	Adaptation Co-Lead	Guides the development of adaptation strategies and their implementation through the co-production and consortium process.	
William Travis	Adaptation Co-Lead		
Leah Wasser	Education Lead	Oversees the development of training plan and material for climate data.	
Imtiaz Rangwala	Climate Science Lead	Provides primary climate expertise to the NC CASC-directed projects; works with boundary organizations to facilitate effective integration of climate research into natural resource management and planning. Rangwala also co-hosts the NC CASC Webinar Series, mentors Prasad Thota; and co-mentors Jilmarie Stephens.	
Heather Yocum	Stakeholder & Communication Lead	Facilitates research-to-operations processes, convenes/structures stakeholder engagement between scientists and information users, expands the stakeholder base and solicits user feedback to refine information content and delivery platforms. Yocum developed the communications strategy, co-hosts the NC CASC Webinar Series, co-mentors Sarah Jaffe and Shelby Ross, and oversees the consortium partner activities. She is also the primary contact for the Tribal Climate Leaders Program, and PI for *Grasslands Synthesis Project*.	
Max Joseph	Open Science Architect	Develops open source, reproducible software, workflows and accompanying trainings to increase access and usability of various data sources.	
Lauren Herwehe Kim	Education Trainer	Assists with the development of course materials for the Climate Science Workshops.	

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James Rattling Leaf, Sr.	GPTWA consultant/ Research Associate	Works with the GPTWA and other Tribal organizations in the NC CASC region to form Tribal engagement plans, identify key climate science training needs, raises awareness of adaptation and planning needs to resource managers in tribal communities, and encourages and recruits students into educational programs. Rattling Leaf also co-mentors Shelby Ross and Phurwa Gurung.	
Dawn Umpleby	Executive Assistant	Provides project support in areas of website development, maintenance, content design, social media platforms, newsletter creation/distribution, logistics planning for events, reporting and budget planning and tracking, including sub-awards to consortium members. Provides support for the Tribal Climate Leaders Program, and Director.	
Katherine Halama	Temp aide - Oct 2020-Feb 2021 (hourly)/Communications Assistant - Mar 2021-current (hourly)	Assists Executive Assistant with website and social media content and maintenance, newsletter content and creation.	
Jilmarie Stephens	Postdoctoral fellow	Conducts research on the future of fire in the North Central region under changing climate conditions. Results will inform the National CASC CAP Fellow Program *Future of Fire* project.	
Sarah Jaffe	Graduate research assistant	Maps land cover, jurisdictional boundaries, and climate data for the *Grasslands Synthesis Project* communications products.	
Phurwa Gurung	Graduate research assistant	Reviews literature on the use of traditional ecological knowledges in the North Central region.	
Shelby Ross	Graduate research assistant	Tribal Climate Leaders Program; reviews literature on Tribal Nations grassland and climate change related goals and challenges.	
Prasad Thota	Graduate research assistant	Develops climate datasets, workflows and tools, and conducts analysis and visualization of stakeholder tracking data.	
Will Crawford	Graduate research assistant	Tribal Climate Leaders Program	

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APPENDIX III: Open Workflows and Datasets, Tool Maintenance, and Project Climate Support for FWS, NPS, and State Wildlife Agencies

Open workflows and datasets:

- Heat stress index projections using MACA (workflow)--Imtiaz Rangwala
- Annual & Seasonal Water Deficit projections using MACA (Evaporative Demand minus Precipitation) (workflow)--Imtiaz Rangwala
- Forest Stress Drought Index gridded dataset for CONUS - historical; 1980-2018--Imtiaz Rangwala
- Standardised Precipitation Index (SPI) projections based on MACA--Imtiaz Rangwala
- R Shiny app for Climate Futures Toolbox (CFT)--Imtiaz Rangwala and Prasad Thota (Link: https://github.com/nc-casc/cft_Shiny_App)
- R Shiny app for Grasslands Productivity (GrassCast) and Climate (GRIDMET) (Link: https://nccasc.shinyapps.io/Grasslands_Productivity_Climate_App/)
- R Shiny app for quantifying events associated with Extreme Accumulation of Evaporative Demand (Link: https://nccasc.shinyapps.io/Evaporative_Demand_Extremes_App/)

Tool Maintenance:

- Continued operations of Landscape Evaporative Response Index (LERI) webtool with NOAA PSL--Imtiaz Rangwala
- Continued operations of Drought Index Portal (DrIP)--Imtiaz Rangwala
- Maintenance of Climate Futures Toolbox (CFT), Evaporative Demand Drought Index (EDDI), LERI R packages--Max Joseph

Project climate support for FWS, NPS and state wildlife agencies:

- FWS SSA on Pygmy Owl (reviewed climate analysis work)--Imtiaz Rangwala
- NC CASC funded project on future mule deer greenscape in WY (USGS+WY Game & Fish + NPS) (co-author on paper being developed)--Imtiaz Rangwala
- NC CASC funded project on breeding waterfowl pairs in US Prairie Pothole Region (USGS+FWS)
- Technical advisor for Regional Conservation Assessment (2020-21) led by The Nature Conservancy (TNC), Biohabitats and Metro Denver Alliance--Imtiaz Rangwala
- Paper on Wolverine Species Status Assessment (SSA) with FWS (submitted in Feb 2021)--Imtiaz Rangwala
- Contribute a paper to a joint special issue with the journals *Climate* and *Earth* on "Climate System Uncertainty and Biodiversity Conservation," titled "Uncertainty, Complexity and Constraints: How do we robustly assess ecological responses under a rapidly changing climate?" --Imtiaz Rangwala and Jane Wolken. Expected submission date: August 2021

APPENDIX IV--Timetable of Consortium Partner Activities

Summary of timetable of consortium partner activities; CU=University of Colorado; CSP=Consortium Science Partners; WCS=Wildlife Conservation Society; UM=University of Montana; SDSU=South Dakota State University; and GPTWA=Great Plains Tribal Water Alliance.

Consortium Partner	Year 2 (Oct 2019-Sept 2020)	Year 3 (Oct 2020-Sept 2021)	Year 4 (Oct 2021-Sept 2022)	Year 5 (Oct 2022-Sept 2023)
CU	• Host virtual CP meeting	● Annual CP meeting, with CSP host	● Annual CP meeting, with SDSU host	● Annual CP meeting, with GPTWA host
CSP		● Host annual CP meeting ● Synergistic Research: *Transformational Drought project (NCASC; Rangwala) *Visualizing Ecological drought project (NOAA-NIDIS; Cross)	● Planned work informed by RAD framework	
WCS	• Postponed due to CP funding	● Ongoing work with WY Game & Fish Department ● Evaluation of WCS adaptation projects + publication ● Virtual workshop on Measuring Climate Adaptation Outcomes (July 2021)	● 2-day workshop -- Adaptation Success (June 2022 target)	
MT	• Postponed due to CP funding	● Workshop with fire stakeholders (Feb 2021) ● Developing science and outreach tools to aid in post-fire vegetation management decisions	● Continue to develop science and outreach tools to aid in post-fire vegetation management decision ● Follow-up workshop (Jan-Feb; possibly moved to Sept)	
SDSU	• Postponed due to COVID-19	● Meetings with local stakeholders to ID climate info and research needs.	● Local meetings ● Host CP meeting	● Local meetings
GPTWA	• 2-day workshop postponed due to COVID		● 2-day workshop	● Host CP meeting

APPENDIX V--Outreach Products/Activities

Peer reviewed journals, non-peer reviewed technical reports and op-eds:
NC CASC researchers/consortium partners appear in **bold** text. ***** indicates a product was not funded by the NC CASC, but leverages NC CASC researchers/consortium partners expertise in support of NC CASC strategic science goals:

- **Balch, J.** 2021. Skip the fireworks this Independence Day, our firefighters need a break. *The Hill*, Published online: 4 July, 2021.
- *****Barsugli, J.J., Ray, A.J., Livneh, B., Dewes, C.F., Heldmyer, A., **Rangwala, I.**, Guinott, J.M., and Torbit, S. (2020). Projections of mountain snowpack loss for wolverine denning elevations in the Rocky Mountains. *Earth's Future*, 8(10): e2020EF001537, https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2020EF001537
- Buono, P., Rondeau, R., Bidwell, M., Monroe, S., Rank, G., Roberts, S., **Cross, M.**, and **Rangwala, I.** (2021). Prioritized Drought Resilience Strategies for the Mancos Watershed. Prepared for Mancos Watershed Group. https://tinyurl.com/8ek638kk
- *****Cattau, M.E., Wessman, C., Mahood, A., and **Balch, J.K.** (2020). Anthropogenic and lightning-started fires are becoming larger and more frequent over a longer season length in the U.S.A. *Global Ecology and Biogeography*, 29(4): 668-681, https://doi.org/10.1111/geb.13058 (*not reported in Year 2*).
- Clifford, K., **Travis, W.R.**, and Nordgren, L.T. (2020). A climate knowledges approach to climate services. *Climate Services*, 18:100155, 10.1016/j.cliser.2020.100155 (*not reported in Year 2*).
- **Crausbay, S.D.**, Sofaer, H., Cravens, A.E., Chafin, B.C., Clifford, K., Gross, J.E., Knapp, C., Lawrence, D.J., Magness, D.R., Miller-Rushing, A., Schuurman, G.W., and Stevens-Rumann, C. (*In Revision*). A science agenda to inform natural resource management decisions in an era of ecological transformation. *BioScience*.
- **Crausbay, S.**, Ramirez, A., Betancourt, J., Bradford, J.B., Cartwright, J., Dunham, J.B., Enquist, C., Frazier, A., Hall, K., Littell, J.S., Luce, C.H., Palmer, R., **Rangwala, I.**, Thompson, L., and Carter, S. (2020). Unfamiliar territory: emerging themes for ecological drought research and management. *One Earth,* 3(3), 337-353, https://doi.org/10.1016/j.oneear.2020.08.019
- *****Cravens, A.E., McEvoy, J. Zoanni, D., **Crausbay, S.**, Ramirez, A.R., and Cooper, A.E. (2021). Integrating Ecological Impacts: Perspectives on drought in the Upper Missouri Headwaters, Montana, United States. *Journal of Weather, Climate, and Society*, https://doi.org/10.1175/WCAS-D-19-0111.1
- **Cross, M.**, Dey, P., Tator, I., Bredehoft R., Mahoney, A., Smith, N., and Wasseen, J. (2020). Climate change and management of river, riparian, and wetlands habitats in Wyoming: Summary from Wyoming Game and Fish Department Climate Change Workshop-April 28-30, 2020. Wildlife Conservation Society & Wyoming Game and Fish Department.
- ***Davis, K.T., Higuera, P.E.**, Dobrowski, S.Z., Parks, S.A., Abatzoglou, J.T., Rother, M.T., and Veblen, T.T. (2020). Fire-catalyzed vegetation shifts in ponderosa pine and Douglas-fir forests of the western United States. *Environmental Research Letters*, 15, 1040b8, https://iopscience.iop.org/article/10.1088/1748-9326/abb9df
- *****Esit, M., Kumar, S. Pandey, A., Lawrence, D.M., **Rangwala, I.** and Yeager, S. (2021). Seasonal to multi-year soil moisture drought forecasting. *Climate and Atmospheric Sciences*, 4:16, https://www.nature.com/articles/s41612-021-00172-z
- *****Fargione, J., Haase, D.L., Burney, O.T., Kildisheva, O.A., Edge, G., Cook-Patton, S.C., Chapman, T., Rempel, A., Hurteau, M.D., **Davis, K.T.,** Dobrowski, S., Enebak, S., De La Torre, R., Bhuta, A.A.R., Cubbage, F., Kittler, B., Zhang, D., and Guldin, R.W. (2021). Challenges to the reforestation pipeline

in the United States. *Frontiers in Forest and Global Change*, 4: Article 629198, https://doi.org/10.3389/ffgc.2021.629198

- ***Higuera, P.E.**, Shuman, B.N. and Wolf, K.D. (2021). Rocky Mountain subalpine forests now burning more than any time in recent millenia. *Proceedings of the National Academy of Sciences of the United States of America*, 118(25):e2103135118, https://doi-org.colorado.idm.oclc.org/10.1073/pnas.2103135118
- Hobbins, M.T., Glaudemans, M., Huntington, J.L., McEvoy, D.J., **Rangwala I.**, Ray, A.J., Tan, X., and **Yocum, H.M.** (2020). Operationalizing an Evaporative Demand Drought Index (EDDI) service for drought monitoring and early warning. Final project report to NOAA Joint Technology Transfer Initiative Program, NOAA Physical Sciences Division, Boulder, CO, March 19, https://tinyurl.com/wpxn3xb
- *Hoell, A., Parker, B.-A., Downey, M., Umphlett, N., Jencso, K., Akyuz, F. A., Peck, D., Hadwen, T., Fuchs, B., Kluck, D., **Edwards, L.**, Perlwitz, J., Eischeid, J., Deheza, V., Pulwarty, R., and Bevington, K. (2020). Lessons learned from the 2017 flash drought across the U.S. Northern Great Plains and Canadian Prairies. *Bulletin of the American Meteorological Society*, 1–46, https://doi.org/10.1175/BAMS-D-19-0272.1
- ***Joseph, M.B.**, Pavlacky, Jr., D.C., and Bartuszevige, A.M. (2021). Data fusion for abundance estimation: community science augments systematically collected removal-in-time distance sampling data. bioRxiv preprint doi: https://www.biorxiv.org/content/10.1101/2021.05.02.442379v1
- *Lukas, J., Payton, E., Deems, J., **Rangwala, I.**, and Duncan, B. (2020). Observations—Hydrology. Ch. 5 in Colorado River Basin Climate and Hydrology: State of the Science, edited by J. Lukas and E. Payton, 154-219. Western Water Assessment, University of Colorado Boulder. doi:10.25810/3hcv-w477, https://wwa.colorado.edu/publications/reports/CRBreport/ColoRiver_StateOfScience_WWA_2020_Chapter_5.pdf
- *Mietkiewicz, N., **Balch, J. K.**, Schoennagel, T., Leyk, S., St. Denis, L.A., and Bradley, B.A. (2020). In the Line of Fire: Consequences of human-ignited wildfires to homes in the U.S. (1992–2015). *Fire*, *3*(3), 50, https://doi.org/10.3390/fire3030050.
- *Oakes, L.E., **Cross, M.S.**, and Zavaleta, E. (2021). Rapid assessment to facilitate climate-informed conservation and nature-based solutions. *Conservation Science and Practice*, e472, https://doi.org/10.1111/csp2.472.
- **Rangwala I.** (2020). Monitoring and predicting drought on our grasslands. Grasslands News. USDA's National Grasslands Council's Spring 2020 Newsletter, pg. 6-8, https://tinyurl.com/sbb7bag
- *Schulz, T.T., Wilmer, H., **Yocum, H.**, Winford, E., Peck, D., Monlezun, A.C., Schmalz, H., Klemm, T., Epstein, K. Jansen, V., Kelley, W., Bruegger, R., Stephen, F., Gazing Wolf, J., Grace, J., Mann, R., and Derner, J. (2020). Campfire conversations at the 2020 Annual Meeting: Insights & lessons learned from "Cuss-and-Discuss" rather than "Chalk-and-Talk." *Rangelands*, https://doi.org/10.1016/j.rala.2021.04.003.
- Schuurman, G.W., Cole, D.N., Cravens, A.E., **Crausbay, S.D.**, Hawkins Hoffman, C., Lawrence, D.J., Magness, D., Morton, J., Nelson, E., and O'Malley, R. (*In Press*). Navigating ecological transformation: Resist-Accept-Direct (RAD) as a path to a new resource management paradigm. *BioScience*.
- *St-Laurent, G.P., Oakes, L.E., **Cross, M.**, and Hagerman, S. (2021). R-R-T (resistance-resilience-transformation) typology reveals differential conservation approaches across ecosystems and time. *Communications Biology*, 4, 39, https://doi.org/10.1038/s42003-020-01556-2.
- ***Yocum, H.M**., Sassorossi, D. and Ray, A.J. (*Accepted with minor revisions*). Assessing the use of climate change information in state wildlife action plans. *Conservation Science and Practice*.

Project-related conference presentations, seminars, webinars, workshops, and public presentations:

- 2020 Academic Data Science Alliance Annual Meeting (15 October, 2020) -- Presentation by James Rattling Leaf, Sr.: From Data Sovereignty to Data Science: Implications for American Indian Self-Determination
- Environmental Law Institute (21 October, 2020) -- Presentation by James Rattling Leaf: Swept Away: Safeguarding Tribal Cultural Heritage from the Impacts of Climate Change
- Group on Earth Observations (GEO) Week 2020 (6 November, 2020) -- Presentation by James Rattling Leaf, Sr.: Every Tribal Nation Has a Data Story: Challenges and Opportunities Moving Forward
- ESA Watercooler Chat (13 November 2020) -- Presentation by James Rattling Leaf: Exploration of Modern Indigenous Knowledge and the Power of Indigenous and Western Science
- Cooperative Institute for Research in Environmental Sciences (18 November, 2020) -- Presentation by James Rattling Leaf, Sr.: Building Relational and Effective Partnerships with Indigenous Communities
- Tribal GIS 2020 (19 November, 2020) -- Presentation by James Rattling Leaf: Every Tribe Has a Climate Story: Climate Assessment Planning on Tribal Lands in the Great Plains
- Lancet Countdown: Tracking Progress on Health and Climate Change (3 December, 2020) -- Presentation by James Rattling Leaf,, Sr.
- GEO Indigenous Summit (7-12 December, 2020) -- James Rattling Leaf, Sr.: Welcome Session, Moderator for COVID-19 Panel and Education/Intergenerational Knowledge Transfer Panel, Closing Ceremony and Remarks
- American Meteorological Society (14 January 2021) -- Panel Discussion by James Rattling Leaf, Sr.: Sixth Symposium on US-International Partnerships- Engaging International Users in the Development of Environmental Satellite Data and Applications
- Inter-American Academy of Geosciences and Applications (9-11 February, 2021) -- Webinar by James Rattling Leaf, Sr.: Engaging with Indigenous Peoples
- Posner Center (25 February, 2021) -- Presentation by James Rattling Leaf, Sr.: Climate Justice and Indigenous Rights
- Warm Regards (22 February, 2021) -- Podcast with James Rattling Leaf, Sr.: Indigenous Climate Knowledges and Data Sovereignty
- Bay Area Environmental Research Institute (3 March, 2021) -- Podcast with James Rattling Leaf, Sr.: Connecting Tribal Lands with NASA Remote Sensing Tools
- Aspen Center for Environmental Studies (4 March, 2021) -- Presentation by Phil Higuera: Colorado's Record-Setting 2020 Fire Season in the Context of the Past 6000 Years
- Navajo Medicine Man Association from Navajo Tribal Nation (14 March, 2021) -- Presentation by James Rattling Leaf, Sr.: Climate Change
- Society for Conservation GIS (1 April, 2021) -- Presentation by James Rattling Leaf, Sr.: Building Effective Partnerships with Indigenous Communities
- South Dakota 'Drought Hour' Webinar (19 April, 2021) -- Presentation by Laura Edwards: Climate Update
- Boulder Labs Diversity Council (21 April, 2021) -- Presentation by James Rattling Leaf, Sr.: Engaging with Native American Communities: Mitakuye Oyasin
- InterTribal Buffalo Council (4 June, 2021) -- James Rattling Leaf, Sr.: 2021 Annual Membership Meeting Panel: Planning for Drought and Resilience to Climate Change
- American Water Resources Association 2021 Virtual Summer Conference (21 July, 2021) -- Panelist James Rattling Leaf, Sr.: Collaborative Approaches to the Use of Earth Observations in Indigenous Communities

Major engagements with regional decision-makers, stakeholders, and resource managers:

- National Academies of Sciences Engineering Medicine: Wildland Fires: Towards Improved Understanding and Forecasting of Air Quality Impacts - A Workshop (23 September, 2020) -- Presentation by Jennifer Balch, *Our Changing Fire Regimes*.
- NC-CASC-funded project resulted in a climate-informed Statewide Habitat Plan in Wyoming that was released by the Wyoming Game and Fish Department in November 2020: https://wgfd.wyo.gov/getmedia/8ba62756-6d1c-4257-8644-82383dfa605a/SHP2020_Final.
- Letter of Invitation to participate in the *Grasslands Synthesis Project* (December, 2020) -- Heather Yocum and Christy Miller Hesed: a formal letter was sent to Tribal Chairs at each of the 30 Tribal Nations in the North Central region with grasslands. This letter described the goals of the Project and invited a member of the Tribal Nation to help us identify grassland management priorities by serving on our Advisory Committee.
- CASC National Climate-Fire Synthesis Workshop (13-15 January, 2021) -- Presentation and participation by Jennifer Balch, Jane Wolken and Jilmarie Stephens.
- High Plains Regional Climate Center Climate and Fire Workshop with Nebraska Forest Service (28-29 January, 2021) -- Presentation and participation by Jilmarie Stephens and Jane Wolken
- Managing Post-fire Vegetation Under Climate Change (February 3-4, 2021) -- Workshop hosted by Consortium Partner University of Montana (Phil Higuera and Kimberley Davis); Participation by Jilmarie Stephens and Jane Wolken.
- Congressman Neguse's First Annual Wildfire Summit (18 February, 2021) -- Panelist presentation by Jennifer Balch, *The Science of Wildfires*.
- Crown Managers Partnership Fire in the Crown of the Continent Fire Forum (22-26 March, 2021) -- Participation by Jilmarie Stephens.
- Hearing of the House Natural Resources Subcommittee on Parks, Forests, and Public Lands (23 March, 2021) -- Molly Cross (Wildlife Conservation Society) testified at a hearing of the House Natural Resources Subcommittee on Parks, Forests, and Public Lands, on the role of federal programs in supporting natural climate solutions in the U.S.
- Measuring Climate Adaptation Outcomes (12-13 July, 2021) -- Virtual meeting hosted by Molly Cross (Wildlife Conservation Society). The purpose of the meeting was to initiate discussion among researchers and practitioners in the NC CASC region about how we define and measure outcomes for climate adaptation practices, with a particular focus on process-based and beaver-related restoration techniques designed to help wildlife and ecosystems adapt to a changing climate.

Fact sheets and blogs:

- Climate Toolbox Case Study: Species Assessments, The Climate Toolbox (ClimateToolbox.org) features Imtiaz Rangwala's climate data work on Species Status Assessments with the U.S. FWS.
- NC CASC (Jennifer Balch and Jane Wolken) partners with Earth Lab and CIRES to compile a list of resources on current fires and air quality: How Bad is the Smoke? Current Fires and Air Quality Resources: Top 10 ways to get up-to-date information on fires and air quality. Published online: 25 August, 2020 (*not reported in Year 2*).

Media mentions:

- Throughout the 2020 wildfire season (*not reported in Year 2*) NC CASC University Director Jennifer Balch fielded 15 media requests for her expertise in wildfire science. A list of these media engagements is located on our website.
- Imtiaz Rangwala quoted in The Guardian: Record-Shattering Heat Wave Bakes Western US, Raising Drought and Fire Concerns. Published online: 18 June, 2021.