CONSTRUCTING CLIMATE RESILIENT COMMUNITIES, LANDSCAPES, AND COASTS IN CALIFORNIA AND NEVADA

PERFORMANCE PERIOD: JUNE 1, 2019–MAY 31, 2020

CNAP
California-Nevada Climate Applications Program
A NOAA RISA team

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What is CNAP?

MISSION: To improve resilience in California and Nevada by providing decision makers usable climate information through integrating cutting edge physical and social science.

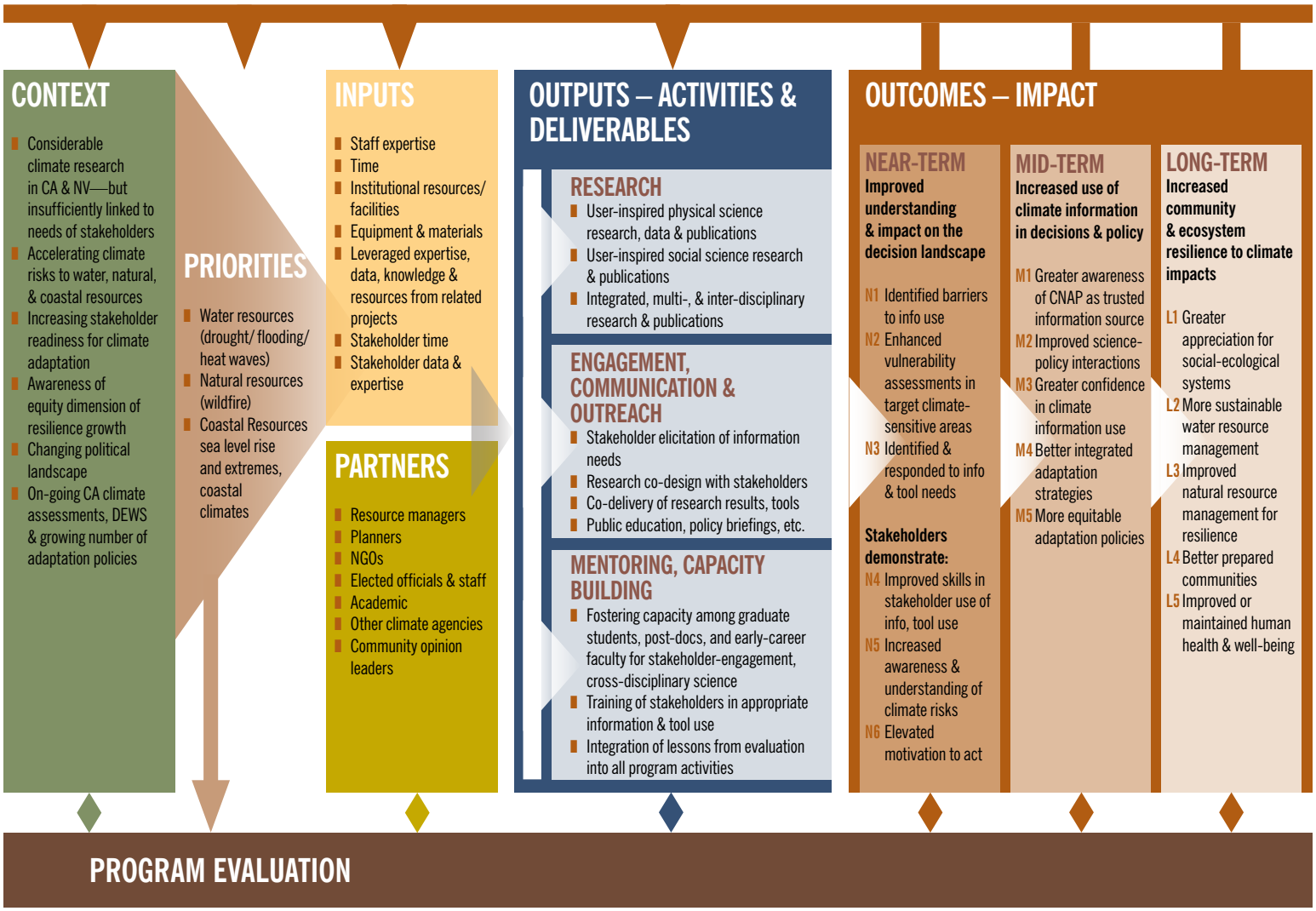
CNAP, CALIFORNIA NEVADA APPLICATIONS PROGRAM, has a long history of providing cutting edge climate science to stakeholders in the region. The program began with an emphasis on California issues in 1999 as the California Applications Program (CAP). In 2011, the team expanded its geographic scope to include Nevada and became CNAP. CNAP's core priority sectors include understanding effects of climate variation on water resources, natural resources and coastal resources (see below), along with other linked systems including societal components.

Since 2005, CNAP has worked closely with the California Energy Commission (CEC) and other State Agencies and has taken a leading role in the first four California Climate Change Vulnerability and Adaptation Assessments, and is currently involved in efforts that will support the fifth California Climate Change Assessment. Importantly, Nevada is currently developing a Climate Strategic Plan in 2020 (to be released on Dec. 1, 2020), and CNAP has engaged with the recently appointed Nevada Climate Policy Coordinator to provide expertise and model results derived from recent and ongoing California Climate Change Assessments. CNAP has also collaborated with California Department of Water Resources (DWR) in providing data, observations and interpretation to better anticipate how climate and associated weather events affect water resources and water hazards in the State. CNAP, working with California agencies including DWR, CEC and the California Ocean Protection Council, has contributed to a better understanding of climate impacts on the California coast, including the occurrence of coastal storms and two iterations of Sea Level Rise Guidance to State Agencies. Another focus of CNAP is working with fire agencies in California, Nevada, and across the western U.S. to investigate effects of climate and weather on wildfire, with important contributions in understanding the strong influence of climate fluctuations upon the regionally varying wildfire patterns, differences in climatic influences across different types of landscape and vegetation, and changes over recent decades towards a more active wildfire regime, with projections of possible enhanced wildfire threat in future decades.

Additionally, CNAP has put new focus on the institutional knowledge in the wildfire community, working with fire fighters to better understand how climate information has and could play into planning and decision making. With increased emphasis on Nevada climate issues, CNAP has worked with Great Basin tribes to understand barriers to climate data and helped develop a resilience plan with Washoe County. Over this past year, CNAP has provided fire agencies with a better understanding of how evaporative demand influence fire weather conditions and how this may change in the future. On a local scale, as an outgrowth of the California fourth Climate Change Assessment, Sierra Nevada Region Report (2018), CNAP has helped the California Tahoe Conservancy to conceptualize the science aspects of a possible climate institute at Lake Tahoe.

Since the inception of the California Nevada Drought Early Warning System (CA/NV DEWS) CNAP has partnered closely with the National Integrated Drought Information System (NIDIS) to coordinate communication and to research topics surrounding drought and water resources.

CALIFORNIA NEVADA CLIMATE APPLICATIONS PROGRAM MODEL



CNAP program model highlights the outcomes, or what the type of products it produces including scientific journal articles, reports, stakeholder workshops, and mentoring early career scientists. The program model also describes the short-term, near-term, and long-term goals for the program.

CNAP TEAM ROLES/RESPONSIBILITIES

DRI

- Tamara Wall
- Tim Brown
- Justin Huntington
- Nina Oakley*
- Kristin VanderMolen*
- Dan McEvoy*
- Nick Kimutis*

- Provide leadership to the social science team and guide collaborative interdisciplinary efforts (CA/NV)
- Primary support for social science research in Nevada and California
- Focus on Nevada stakeholder climate information needs
- Provide support and expertise to California-based team members
- Train postdocs and early-career faculty
- Support evaluation design and implementation
- Co-manage media and social media outreach and engagement

SCRIPPS

- Dan Cayan
- Julie Kalansky*
- David Pierce
- Alexander Gershunov
- Haley Mcinnis*
- Tom Corringham*
- Josh Mumford*

- Provide leadership to the physical science team (CA/NV)
- Lead role in physical science research
- Focus on California stakeholder climate information needs
- Provide support and expertise to Nevada-based team members
- Train postdocs and early-career faculty
- Overall program management
- Co-manage media and social media outreach and engagement

ADDITIONAL SUPPORT

- Susanne Moser, Moser Research & Consulting
  - —Social science research in California
  - —Support evaluation design and implementation
- LeRoy Westerling, UC Merced
  - —Research on wildfire and climate impacts in the Sierra Nevada
- Shraddhanand Shukla* UC Santa Barbara
  - —Drought monitoring and forecasting
- Mike Dettinger, USGS Retired
  - —Hydrology and extreme events
- Dennis Lettenmaier, UCLA
  - —Hydroclimatology
- Duane Waliser, JPL
  - —Atmospheric sciences

*Early Career CNAP Scientists, postdoctoral fellows, or students.

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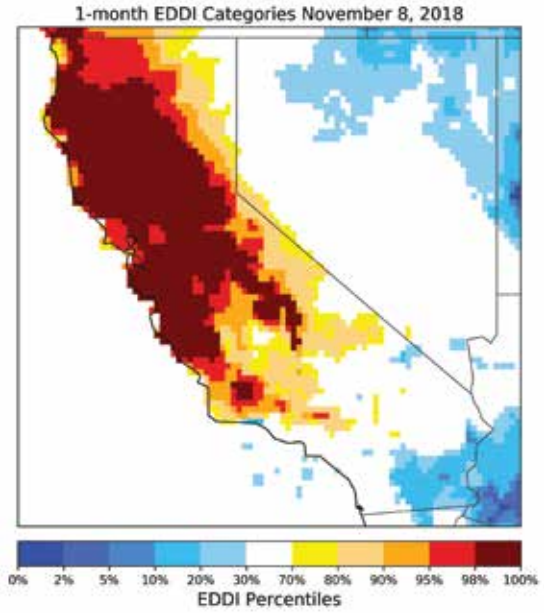
PROUDEST ACCOMPLISHMENT THIS PAST YEAR:

Applications of EDDI on Multiple Timescales

CNAP RESEARCHER, D. MCEVOY is leading multiple efforts related to the application of the Evaporative Drought Demand Index (EDDI). EDDI examines how anomalous the atmospheric evaporative demand (E0; also known as "the thirst of the atmosphere") is for a given location and across a time period of interest. The current EDDI status throughout the US is updated daily (https://psl.noaa.gov/eddi/). This is a project that examines EDDI and the application of the drought indicator on several different timescales that brings together multiple programs under the NOAA Climate Prediction Office including RISA, NIDIS and SARP.



The 1 month EDDI from November 8, 2018, the day the Camp fire started in Northern California and the Woosley fire started in Southern California The Camp fire was the deadliest and most destructive fire in California's history. Data for figure from https://psl.noaa.gov/eddi/

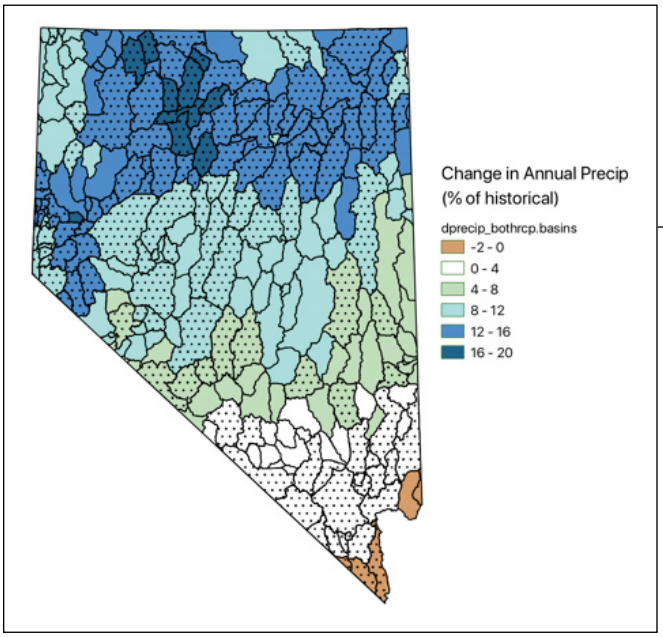
Results from a SARP research project McEvoy et al. (2019) showed the EDDI at 2-5 month time scales is correlated to dead fuel conditions. Through this project and subsequent support through NIDIS and RISA, CNAP researchers McEvoy and Brown have worked with Predictive Services, an agency that provides decision support information to be more proactive in anticipating significant fire activity, to integrate EDDI in the wildfire condition briefings. Predictive Services is now using EDDI in the weekly updated national weather and fuels briefings (https://sites.google.com/view/ps-weather-and-fuels-main-site/home) for fire potential related to drying of fuels. This has grown from EDDI initially only being used by Predictive Services in California about two years ago.

Currently, McEvoy is leading a project working with other CNAP researchers, Pierce, Kalansky and Cayan to understand how EDDI and Standardized Precipitation Evapotranspiration Index (SPEI) will change in the future using downscaled global climate model data. Using daily 2-week EDDI as an indicator of extreme fire potential, this work has shown an increase of 6-10 times the number of days exceeding the 95th percentile for summer and 4-6 times for autumn by the end of the century—similar to the observed number of days during the autumn fire of 2017 and 2018 in northern California. Likewise, the occurrence of extreme droughts based on 3-year SPEI below the 5th percentile is projected to increase substantially by late century (17-73% of years). Understanding how these drought metrics change on the climate timescale at the local level provides fundamental information to support the development of long-term adaptation strategies for wildland fire and water resource management. The data from this research effort will also be included in the Manzanita Climate Resilience Project and the Drought Starts and Stops Project discussed within the report.

Additionally, the EDDI and E0 work became part of an international project, connecting West Africa users to cutting edge resources: Integrating sub-seasonal climate forecasts in agricultural, rangeland, and water-planning missions. This project is being led by CNAP researcher S. Shukla, and through the CNAP connection, McEvoy and Shukla were able to apply the work that has been done in California and Nevada to West Africa. The international application of EDDI and E0 forecasts illustrate the broad reach of this work.

New Partnerships and Focus Areas

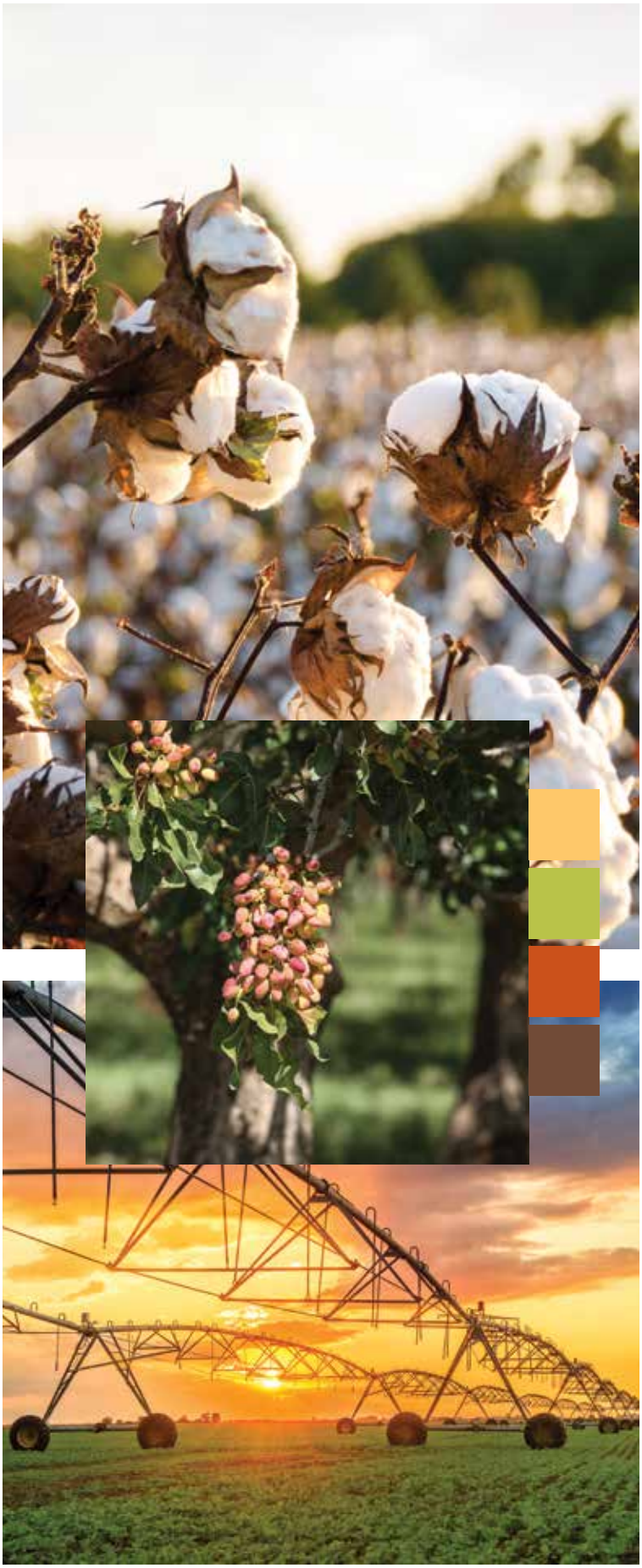
CLIMATE CHANGE IMPACTS ON HYDROLOGY IN NEVADA (DETTINGER): Dettinger is analyzing hydrology data produced by running downscaled GCM through the VIC hydrology model for the hydrographic basins of Nevada (provided by Pierce and Cayan as part of the California 4th Climate Change Assessment). Dettinger presented these early results at the Nevada Water Resources annual conference in February, and has discussed them with Kristen Averyt, Special Climate-Change advisor to the NV Governor, Brad Crowell, NV Secretary of Conservation and Natural Resources, and Jim Lawrence, NV Division of Water Resources, in context of their developing NV Climate-Change Strategy document. Some results of this analysis may be used as examples of what a climate change assessment for Nevada might look like. This sort of comprehensive climate assessment across the State has not been done to date.



Percent change in precipitation relative to historical by 2070–2099, averaged over both RCP 4.5 and RCP 8.5 (a reduced greenhouse gas and business as usual greenhouse gas emission scenario) for Nevada's State Engineer's 256 hydrographic basins.

BUSINESS DISRUPTION AND ADAPTATION SURVEY (VANDERMOLEN AND WALL): VanderMolen and Wall are working with the Center for Economic Development at Chico State University to conduct a survey that will explore how businesses learn from and adapt to disruptive weather/climate-related events (i.e., wildfire) and, potentially, compounding events (i.e., Covid-19 and wildfire). This project developed out of the initial intention to conduct a wildfire smoke businesses disruption survey in collaboration with NOAA and NIST, but has taken different shape with the involvement of Chico State and current restrictions on travel and in-person interaction. Both the new partnership and the new topic area present the potential to expand relationships and research into northern California.

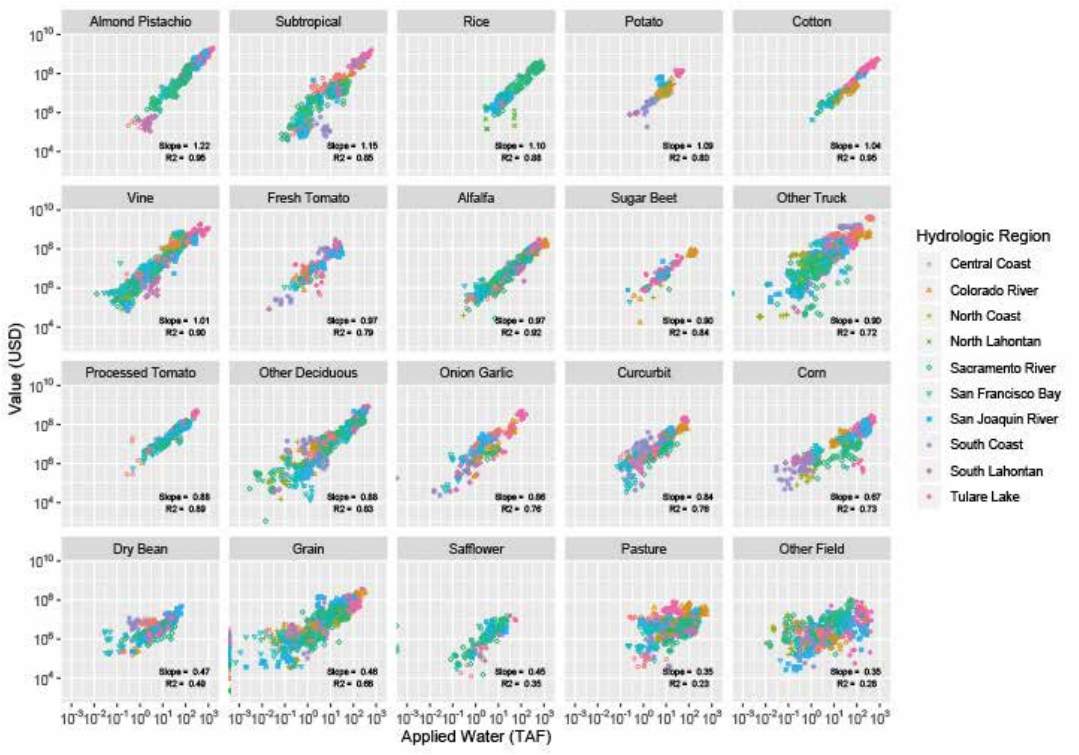
MANZANITA TRIBE CLIMATE RESILIENCE PLAN (KALANSKY, CAYAN WITH CLIMATE SCIENCE ALLIANCE): The CNAP team was invited to partner with the Climate Science Alliance and the Manzanita Band of Diegeño Mission Indians of the Kumeyaay Nation to support the development of the Manzanita 2019 Tribal Resilience Project. The project includes the integration of regionally-specific climate science and Traditional Knowledge to advance Manzanita's climate resilience planning, helping safeguard the Tribe's cultural and traditional resources and practices. The project includes the collaborative efforts of Manzanita community members and staff, the Climate Science Alliance team, and other regional partners. Additionally, the project will leverage the Climate Science Alliance Tribal Working Group, which CNAP is a participant, to coordinate and communicate resilience actions and ensure that the project has a broader impact for Tribes across the region. The team had the opportunity to visit the Reservation, meet with Tribal members and staff, and share ideas and stories to include in the project.



WATER USE AND AGRICULTURAL PRODUCTIVITY CALIFORNIA (CORRINGHAM AND CAYAN):

Corringham is using a 17-year (1998 to 2015) annual county-aggregated water balance data set obtained from the California Department of Water Resources to investigate water supply, water use and water benefits in California. This data, which is a newly developed and the heretofore most resolved picture of statewide water supply and water use, is being matched to county-aggregated annual crop-specific USDA National Agricultural Statistics Service records of crop yields and revenues to quantify the effects of climate variability on agricultural yields and revenues across California. Early results (Figure 1) illustrate the relative value of applied water by crop type and hydrologic region across California. Annual applied water in thousands of acre feet (TAF) by county is plotted against revenue in inflation-adjusted 2020 U.S. dollars by crop type. The crops are ordered by the revenue to applied water elasticities, i.e., the slopes of regression lines through the data. Crops that provide the greatest revenue per TAF of applied water include almonds and pistachios, subtropical crops (e.g. citrus fruits), rice, potatoes, and cotton. Crops that provide the lowest revenue per TAF of applied water include field groups, pasture, safflower, and grain. Spatially, some variability in revenue per applied water is observed across hydrologic regions. The next step in this project is to link these data sets to climate and hydrologic data in order to estimate crop productivity in different climate states over the sample time period over which there has been significant variability in drought and climate conditions. The results should be useful in planning agricultural adaptation and resiliency efforts to future changes in climate across the region. Researchers are also looking to expand the analysis to Nevada if comparable water balance data can be obtained from the Nevada Department of Water Resources.

water supply



Annual applied water and agricultural revenue by county by crop type from 1998 to 2015. Subplots are ordered by elasticity of revenue to applied water. R-squared values for the regressions are indicated. Points are colored by California DWR Hydrologic Region. Each point represents an individual county year.

PUBLIC HEALTH IMPACTS FROM CLIMATE EXTREMES: Leveraging an University of California Campus project, Multicampus Research Programs and Initiatives (MRPI), CNAP researcher A. Gershunov and colleagues have greatly advanced research on the health impacts of extreme weather and climate patterns, particularly via wildfire smoke. Several papers have been published on this topic and expanded our network of stakeholders who will be instrumental in having our results being used in developing warnings and intervention strategies. In particular, Gershunov has a new partnership with Sydney Leibel, a pediatric allergist/immunologist at Rady Children's Hospital-San Diego. Dr. Leibel led a study on the impacts of wildfire smoke on children's health that was published at the end of 2019, to which A. Gershunov, T. Benmarhnia and R. Aguilera contributed. The collaboration with Dr. Leibel and his colleague Margaret Nguyen, a physician in the Emergency Medicine Division of Rady Children's Hospital will continue this upcoming year.

APPLICATION OF CNAP RESEARCH AND OUTPUTS:

Informing Plans and Policies

- Originally only used in California about two years ago, Predictive Services is now using EDDI, the Evaporative Drought Demand Index, in the weekly updated national weather and fuels briefings (https://sites.google.com/view/ps-weather-and-fuels-main-site/home) for fire potential related to drying of fuels.

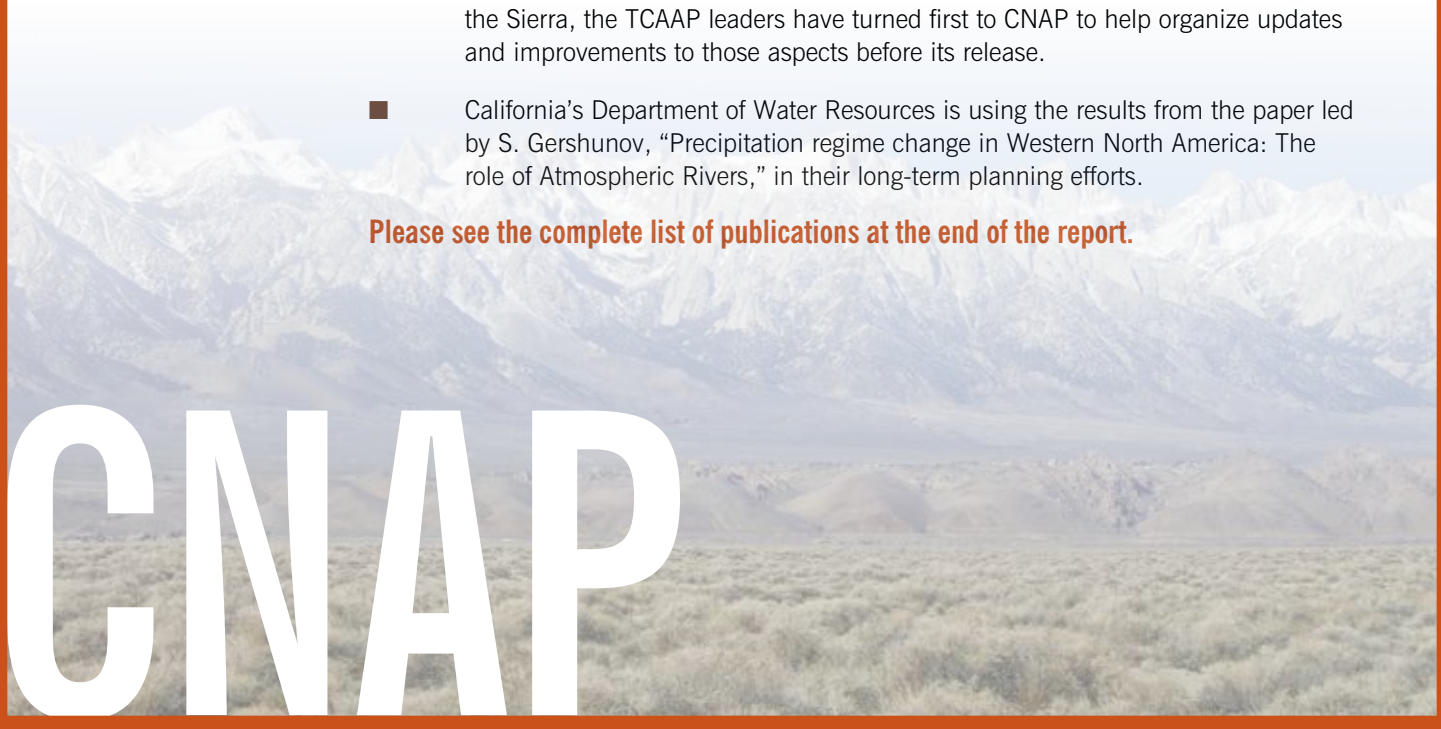
- The City of Carlsbad integrated information on the ecological impacts of climate change from the San Diego Ecosystem Assessment (https://www.climatesciencealliance.org/sdc-ecosystems-assessment) into the Poinsettia Station Vernal Pool Preserve Management Plan. This plan will be used to guide long-term management of a Vernal Pool Preserve. The Ecosystem Assessment also provided scientific data to support Carlsbad in seeking habitat protection for five vernal pool species.

  From Mike Grim, Senior Program Manager/CAP Administrator at City of Carlsbad, "*I think her work is an excellent example of climate smart conservation planning and highlights the value of having downscaled modeling and localized assessments.*"

- Stakeholders have recently questioned some of the aspects of the Tahoe Climate Adaptation Action Plan (TCAAP). As a result of past and recent CNAP activities in the Sierra, the TCAAP leaders have turned first to CNAP to help organize updates and improvements to those aspects before its release.

- California's Department of Water Resources is using the results from the paper led by S. Gershunov, "Precipitation regime change in Western North America: The role of Atmospheric Rivers," in their long-term planning efforts.

Please see the complete list of publications at the end of the report.



Outreach and Engagement Activities

CNAP team members made over 50 presentations about regional weather and climate, and participated in more than 30 interviews.

CALIFORNIA DEPARTMENT OF WATER RESOURCES (DWR) "PLANNING FOR CHANGE" SUMMIT: CNAP researchers Dettinger, Gershunov and Cayan participated in California Department of Water Resources' "Planning for Change" climate change vulnerability and adaptation Summit, held September 2019 in Lake Tahoe. The Summit brought together staff from DWR, stakeholders, scientists and others to develop a shared understanding of potential impacts on water resources, and discussed a set of tools and approaches to assess and plan for climate change. Innovation and adaptation strategies at the State and local levels were discussed, with specific focus on informing DWR's modeling approaches. Gershunov, Dettinger and Cayan made invited presentations regarding atmospheric rivers, drought and other key drivers of benefit and potential hazard in the "Exploring Risk" session and participated in discussions during the evening and the following day that provided input to DWR organizers.

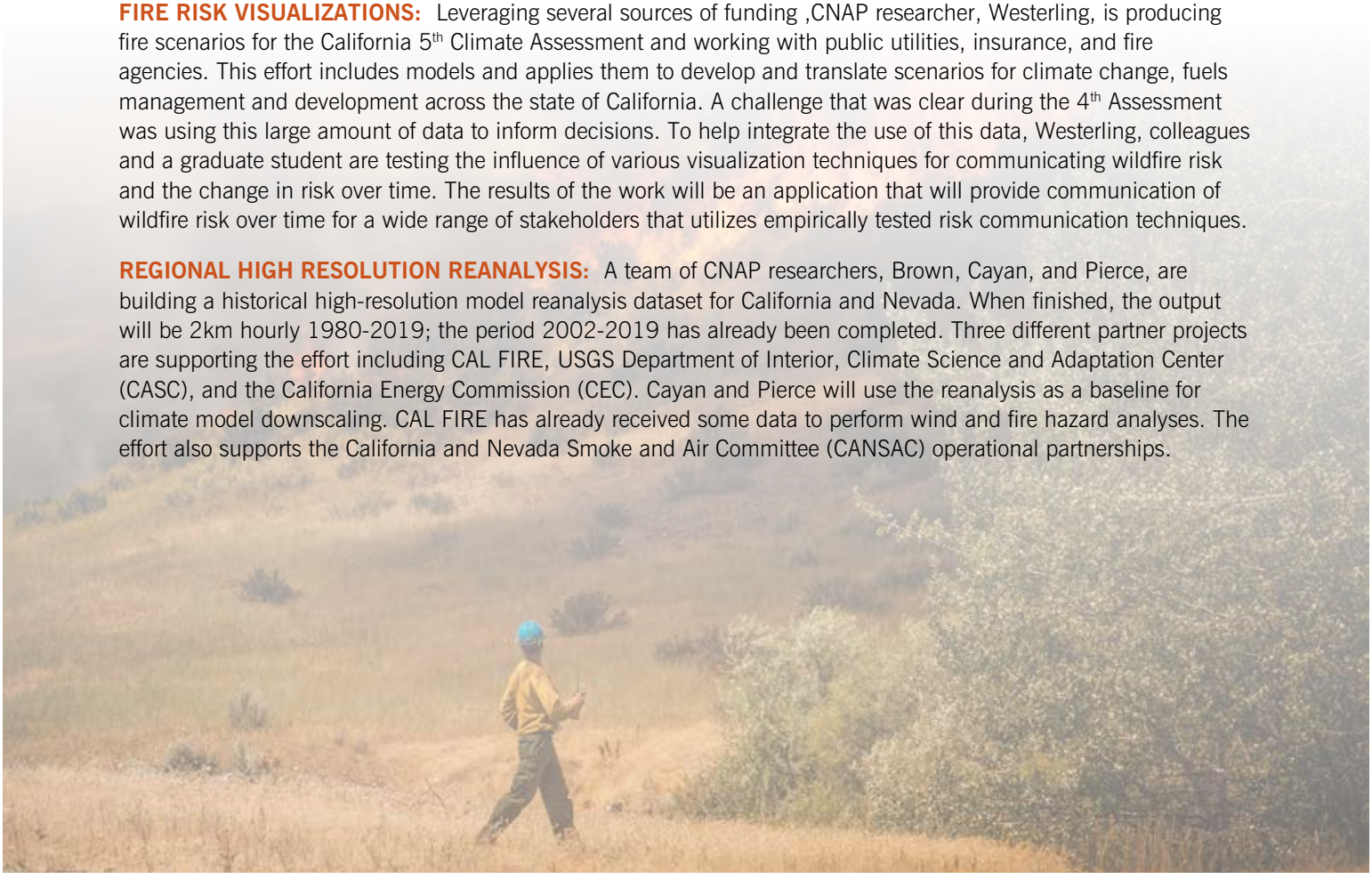
Initiatives to Advance

SAN DIEGO AMERICA PLANNING ASSOCIATION (APA) REPORT: CNAP researchers are working with planners from the APA – Regional and Intergovernmental Planning Division in San Diego to develop a white paper that identifies regional and local government plans for the San Diego region that will require reviews and updates to address impacts of climate change, pursuant to State laws and other guidance. This directly builds upon the San Diego regional report that was part of the California 4th Climate Change Assessment. Although this is focused on San Diego, it will have implications for other cities and counties throughout California. This is also meant to provide information that can be included in the regional reports that will likely be part of the 5th Climate Change Assessment.

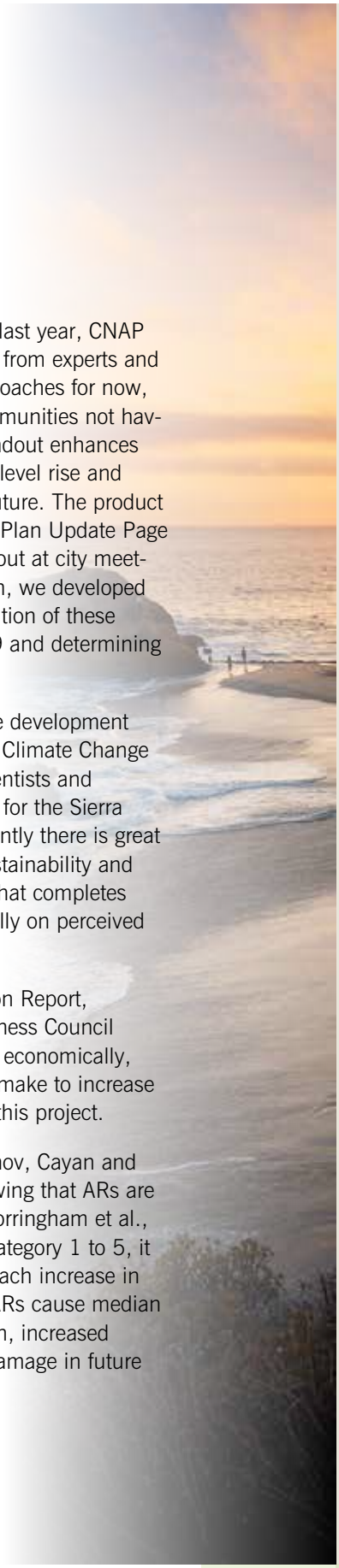
NEVADA CLIMATE ASSESSMENT: CNAP has recently agreed to support State of Nevada's new climate change planning effort by leveraging on-going CNAP California Climate Change Assessment research under the soon to develop 5th California Climate Assessment and the previous 4th California Climate Assessment. This effort will assist the Nevada State Climate Coordinator to learn from and leverage work that has been already done in the California Assessments. Given its previous work in California climate change processes and with Nevada climate-impacted stakeholders, the CNAP team is ideally situated to provide this support to Nevada's efforts around climate change mitigation, adaptation, and resiliency planning. Working with the Nevada Climate Coordinator and the 12 topical committees already established, we are going to develop a preliminary process design for how the state can focus its efforts and resources to produce a climate impact assessment. Ideally, this would act as an addendum to the Nevada climate mitigation plan which is scheduled for release on December 1, 2020. A second phase would identify data and analyses that could be extended into Nevada or revised to support the development of a Nevada climate impact assessment.

FIRE RISK VISUALIZATIONS: Leveraging several sources of funding ,CNAP researcher, Westerling, is producing fire scenarios for the California 5th Climate Assessment and working with public utilities, insurance, and fire agencies. This effort includes models and applies them to develop and translate scenarios for climate change, fuels management and development across the state of California. A challenge that was clear during the 4th Assessment was using this large amount of data to inform decisions. To help integrate the use of this data, Westerling, colleagues and a graduate student are testing the influence of various visualization techniques for communicating wildfire risk and the change in risk over time. The results of the work will be an application that will provide communication of wildfire risk over time for a wide range of stakeholders that utilizes empirically tested risk communication techniques.

REGIONAL HIGH RESOLUTION REANALYSIS: A team of CNAP researchers, Brown, Cayan, and Pierce, are building a historical high-resolution model reanalysis dataset for California and Nevada. When finished, the output will be 2km hourly 1980-2019; the period 2002-2019 has already been completed. Three different partner projects are supporting the effort including CAL FIRE, USGS Department of Interior, Climate Science and Adaptation Center (CASC), and the California Energy Commission (CEC). Cayan and Pierce will use the reanalysis as a baseline for climate model downscaling. CAL FIRE has already received some data to perform wind and fire hazard analyses. The effort also supports the California and Nevada Smoke and Air Committee (CANSAC) operational partnerships.



Building Expertise of Decision Makers to Prepare and Adapt



SEA LEVEL RISE AND PLANNING FOR UNCERTAINTY (KALANSKY): As reported last year, CNAP with the Tijuana National Estuarine Research Reserve developed a handout with input from experts and stakeholders using regionally specific sea level rise data that discusses adaptation approaches for now, the near term, and the long term. The handout was a result of planners in coastal communities not having ways to present both the data and approaches to a diversity of audiences. This handout enhances planners' ability to communicate about the current scientific information related to sea level rise and adaptive management approaches to be prepared for extreme events now and in the future. The product was highlighted on the Oceanside, a city in Northern San Diego County, Local Coastal Plan Update Page (https://www.ci.oceanside.ca.us/gov/dev/planning/local_coastal.asp) and was handed out at city meetings by the NGO Preserve Calavera (https://preservecalavera.org/?p=2456). In addition, we developed regionally specific handouts for Los Angeles County and the Central Coast. The distribution of these handouts has been limited in part due to minimal engagement as a result of COVID-19 and determining how best to interact with planners.

TAHOE CLIMATE INSTITUTE (DETTINGER): Dettinger is actively participating in the development of a Tahoe Climate Institute. This is an outgrowth of CNAP leadership on California 4th Climate Change Assessment Sierra Nevada Region Report. As part of this, Dettinger talked with 27 scientists and science managers to identify, document, and plan for climate-science needs and goals for the Sierra Nevada, and potentially beyond, to make such an institute as useful as possible. Currently there is great enthusiasm about this institute taking the form of a Feinstein and Reid Institute for Sustainability and Climate Change at Lake Tahoe. Over this next year, Dettinger will be part of the team that completes the Tahoe climate institute planning document, with a possible journal article specifically on perceived science needs across Sierra Nevada, California and the West.

Another outcome of the California 4th Climate Change Assessment Sierra Nevada Region Report, Dettinger has been asked to be part of a Technical Advisory Group that the Sierra Business Council is putting together for a Sierra region-wide assessment of "how Sierra communities are economically, socially, and environmentally vulnerable to climate change, and investments they can make to increase their adaptive capacity." The Sierra Nevada Region Report is forming the backbone of this project.

FLOOD DAMAGES FROM ATMOSPHERIC RIVERS: Corringham along with Gershunov, Cayan and other colleagues, investigated flood damage caused by Atmospheric Rivers (ARs), showing that ARs are the primary weather drivers of flood damages throughout the western United States (Corringham et al., 2019). Using flood insurance records and a recently developed AR scale varies from category 1 to 5, it was found that flood damages increase exponentially with AR intensity and duration: each increase in AR category corresponds to roughly a tenfold increase in damages. Category 4 and 5 ARs cause median damages in the tens and hundreds of millions of dollars, respectively. Rising population, increased development, and climate change are expected to worsen the risk of AR-driven flood damage in future decades.

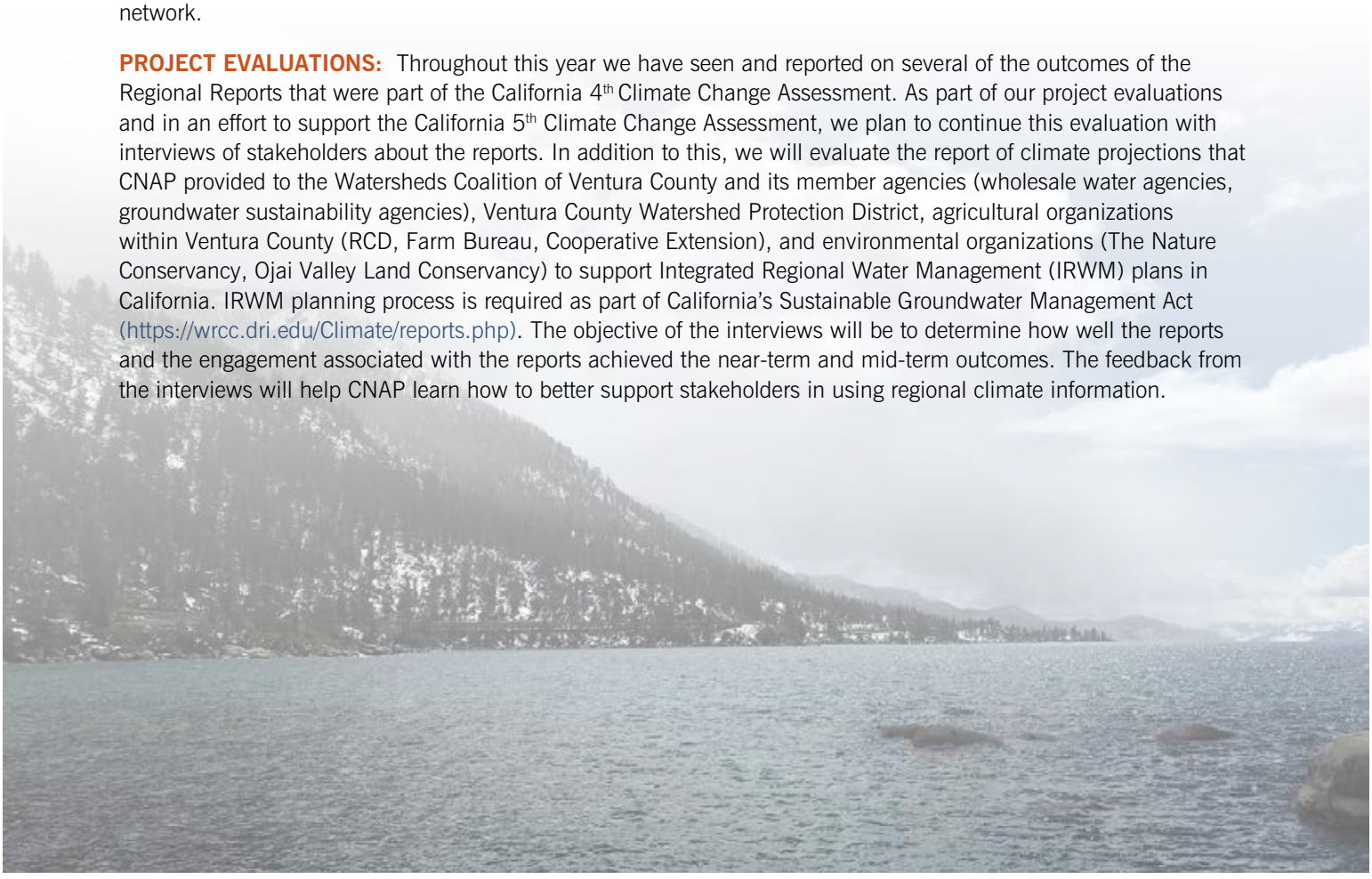
Evaluation

PROGRAMMATIC EVALUATIONS: CNAP INTERNAL MENTORING (MOSER): CNAP has embraced an effort to more fully understand how mentoring activities happen in our network, their impact, and how we can improve and be more effective in our mentoring practices. This is relevant, as many RISA investigators have noted that training early-career scientists in co-production climate research is a key component in capacity building and climate adaptation efforts. In particular, we wanted to better understand what mentoring practices have the most positive impact, what practices are commonly used successfully, and what the barriers to successful mentoring are in CNAP. CNAP researcher, Moser, did the evaluation of mentoring within CNAP which was completed in December 2019. The evolution included both a survey and interviews with CNAP members. CNAP learned a lot about mentoring and being a mentee as it relates to CNAP, and more broadly as it relates to being a mentor/mentee.

There was a wealth of information that came out of the mentoring evaluation. Two high level findings that resulted from the evaluation were: (1) Within CNAP we rarely explicitly discuss mentoring, nonetheless almost the entire team acknowledges that it is an important part of CNAP. (2) Although CNAP has not been very explicit in how to approach mentoring, it has been an overall good experience in most cases. There are several paths towards improving mentoring at CNAP. The first is for mentors and mentees to develop a mentoring plan that discusses goals of the mentees and determine the best sort of communication to support the mentor in reaching the goals. CNAP also discussed supporting trainings to help researchers become better mentors, but has yet to pursue such trainings. Also, as a result of the evaluation, CNAP has started bi-monthly social scientists calls in addition to our monthly calls.

The mentoring evaluation methods and instruments that CNAP developed can be potentially utilized across the RISA network.

PROJECT EVALUATIONS: Throughout this year we have seen and reported on several of the outcomes of the Regional Reports that were part of the California 4th Climate Change Assessment. As part of our project evaluations and in an effort to support the California 5th Climate Change Assessment, we plan to continue this evaluation with interviews of stakeholders about the reports. In addition to this, we will evaluate the report of climate projections that CNAP provided to the Watersheds Coalition of Ventura County and its member agencies (wholesale water agencies, groundwater sustainability agencies), Ventura County Watershed Protection District, agricultural organizations within Ventura County (RCD, Farm Bureau, Cooperative Extension), and environmental organizations (The Nature Conservancy, Ojai Valley Land Conservancy) to support Integrated Regional Water Management (IRWM) plans in California. IRWM planning process is required as part of California's Sustainable Groundwater Management Act (https://wrcc.dri.edu/Climate/reports.php). The objective of the interviews will be to determine how well the reports and the engagement associated with the reports achieved the near-term and mid-term outcomes. The feedback from the interviews will help CNAP learn how to better support stakeholders in using regional climate information.



CNAP Contributions to National Integrated Drought Information System (NIDIS) and the CA/NV Drought Early Warning System (DEWS):

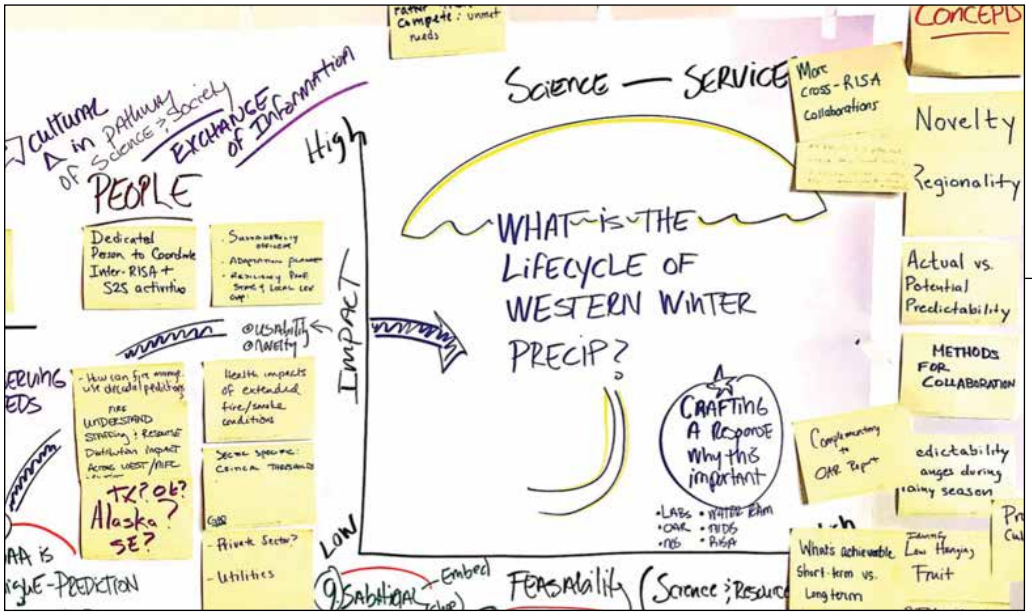
NIDIS OUTREACH AND ENGAGEMENT

NIDIS BI-MONTHLY WEBINAR SERIES: CNAP participates in and co-hosts with NIDIS a bi-monthly CA-NV DEWS *Drought & Climate Outlook* webinar series designed to provide stakeholders and other interested parties in the region with timely information on current drought status and impacts, as well as a preview of current and developing climatic events such as ENSO, stream forecasts, etc. The webinars during this reporting period have all had over 100 attendees and the May webinar had over 200 attendees. The CNAP team works with A. Sheffield in brainstorming topics and speakers. CNAP's presentations over this year were the following:

- September 2019: S. Gershunov – Precipitation Regime Change in Western North America: The role of Atmospheric Rivers
- November 2019: D. McEvoy – Update; J. Kalansky – Outlook; Tools for the Winter (Both)
- March 2020: B. Hatchett – Update
- May 2020: D. McEvoy – Update

S2S WORKSHOP: CNAP organized a workshop with a focus, on phenomena and forecasts on timescales from subseasonal to seasonal to decadal (S2S2D), as applied to the western United States including Alaska, to take advantage of commonalities in forecast applications and forecast drivers. The workshop topic was selected by CNAP and NIDIS based on the NIDIS priorities and was different than the original topic in the proposal. The overall goal is for RISA research scientists and other investigators in the Western region and Alaska to better understand and provide feedback to the S2S2D efforts on-going across NOAA.

A key concept put forward in the meeting was to identify a "Grand Challenge" umbrella topic that would be supported by a within-NOAA research focus and external partner funding opportunities. The topic that emerged was "Cool Season Precipitation in the Western U.S." aligning with one of four pilot projects that are proposed in a report Congress on S2S. Under this topic attendees discussed the entire "lifecycle" of cool season precipitation. This research campaign would incorporate advanced observations, modeling, diagnostics and theory, and would explore fluctuations in timing, amplitude and duration of the cool precipitation season as well as investigation of the beginning, ending and within season interludes. During the discussion attendees highlighted the need for long term planning and coordination within NOAA to focus efforts on the Grand Challenge.



Sample of the wall charts that captured the discussion on how to ways to move S2S2D research and applications forward within NOAA.

Researchers also discussed the importance of smaller scientific research questions, both physical and social science that need to be incorporated under the larger research umbrella to achieve long term goals set under the Grand Challenge topic. The funding opportunities under this Grand Challenge would require broad community participation and could build in stakeholders and attendant forecasting requirements.

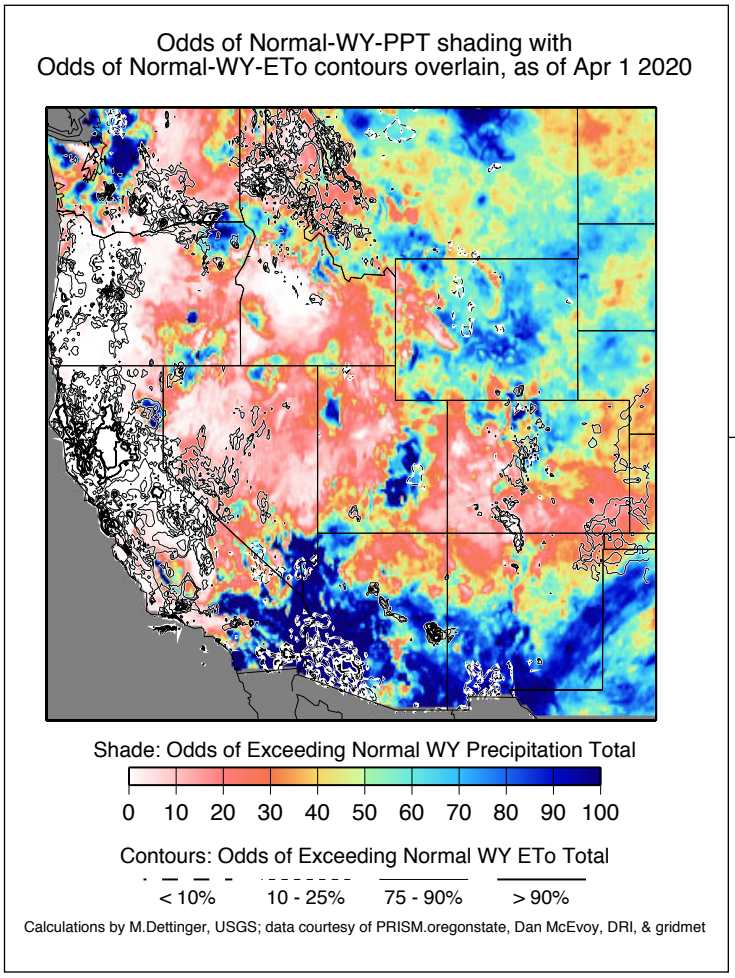
In support of, and in addition to this Grand Challenge, workshop participants developed a set of key concepts and suggestions (with additional funding) to address gaps and seize on opportunities noted above.

1.	Better leveraging week 1 and week 2 forecasts in applications offering significant skill, with follow-on to evaluate and possibly apply 2-4 week products.
2.	Designate a person within NOAA programs to coordinate and identify collaboration and integration opportunities; this might consider models implemented by PACE, SIPD Water Center, or Greg Frost Liaison programs.
3.	Develop a process to learn how regional practitioners are using existing S2S2D products and determine what is working and what are the barriers.
4.	Develop a 'sabbatical fund' for NOAA and university researchers to work collaboratively on specific projects/challenges related to S2S2D utilization and/or scientific questions.
5.	Provide small levels of funding for "Safe to Fail" projects in order to advance in bite size pieces.
6.	Convene cross-State meetings for current and future S2S2D products (e.g., annual science meeting between internal NOAA researchers and external researchers) and coordination planning.
7.	Leverage EDDI forecast products for regional scale (fire management, agriculture) and understand how same products may be used differently regionally. Learn how best to support regional differences.

COPING WITH DROUGHT RESEARCH

RED FLAG PROJECT: CNAP Researchers Brown and Wall are working on a project with multiple NOAA partners and stakeholders to review and revise fire watches and earnings, particularly the Red Flag Warning. Over this past year, the majority of work on the Red Flag Project has focused on working with the Technical Advisory Committee (TAC), made up of NOAA and fire agency personnel, on identifying promising proxies for fire behavior/fuel conditions that could be incorporated with percentiles for weather variables (relative humidity, temperature, wind speed). The TAC has met on a monthly-to-quarterly basis, with fewer meetings over the fire season and more frequently during the winter months. There have been a number of lively conversations around what is desirable (including fuel conditions in the RFWs) and what is feasible, given current constraints nationally, working within the existing NWS structure for operational products. While some of these products are available locally via the Missoula Fire Lap, there is not, at this time, a plan to scale this pilot up to the national level. Engagement this year will focus moving forward with an identified proxy for fuel conditions and developing a plan to test initial products with selected WFOs.

DROUGHT TRACKING PRODUCTS (DETTINGER): CNAP has several drought monitoring efforts that have continued throughout this most recent year. Researcher Dettinger continued development of early-warning drought indicators for California and Nevada, and across the West. These drought indicators include snow-plus-reservoir summaries which are posted on the CNAP website for California and broken down by region (https://scripps.ucsd.edu/programs/cnap/water-storage-tracking-in-california/). This page was the most visited page on the CNAP website with over 1,000 views. In addition to the snow-plus-reservoir summaries that are on the CNAP website, Dettinger is also producing similar tracking for Lake Tahoe Basin, Yuba-Feather River Basins, and the Upper Colorado River Basin. He regularly posts these on his Twitter account, for which he has over 1,500 followers.



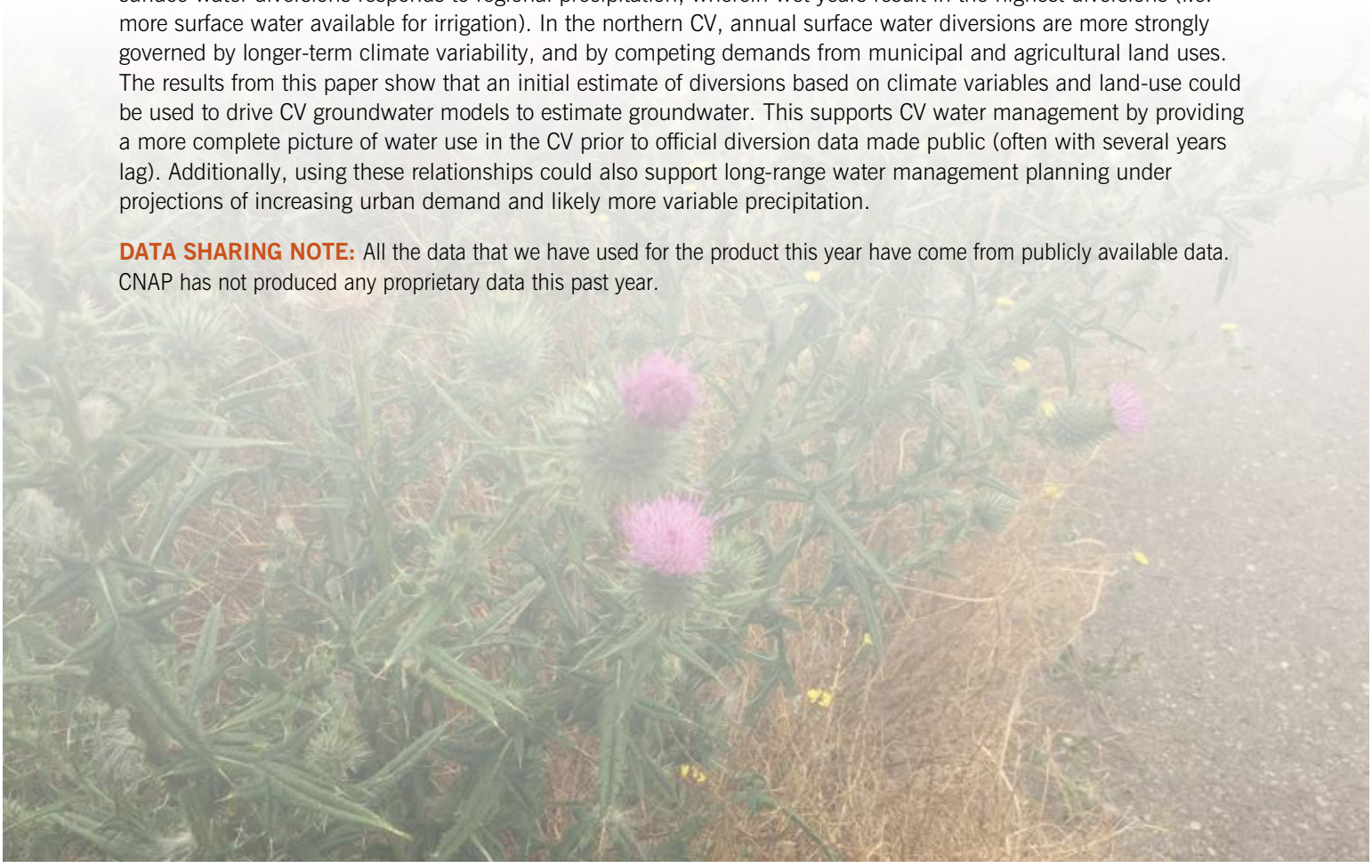
Dettinger is also calculating odds of reaching normal water-year evaporative demand totals across the West on a monthly basis, to complement the odds of reaching normal WY precipitation totals that he developed earlier and passed along to the Center for Western Weather and Water Extremes at Scripps Institution of Oceanography (https://cw3e.ucsd.edu/odds-of-normal-water-year-precipitation/) for their maintenance and publication each month. Dettinger is still developing (at beta levels) the communications of these indicators and is working to fully automate their production as well as document them in the literature.

Odds of normal water-year precipitation (shaded) with the odds of normal water-year ETO in contours overlain. ETo odds overlay map shows strong "complementary relation" patterns with precipitation. ETo also is now pulling towards even drier outcomes as compared to precipitation alone.

DROUGHT STARTS AND STOPS (MCINNIS, PIERCE, KALANSKY, CAYAN): This project examines both the physical science and the social science of when droughts in California and Nevada were declared and when the droughts ended. The project integrates both social and physical science by discussing the research collectively on project calls. The social discourse analysis is beginning to highlight different stakeholders, elevating their arguments and understandings of drought according to their positions. The research has made clear that the positions of stakeholders within politics and the economy has implications for drought declarations and the definitions of drought. Preliminary results indicate that the physical indicators of Northern California carry far more weight than those of Southern California in declaring drought. In the historical analysis, VIC modelling showed that physical indicators like runoff in Northern California were more tightly linked to drought declarations than in other regions. Then, preliminary analysis using future climate projections showed that this difference between Northern California and Southern California is likely to increase and Southern California is likely to experience more conditions that should lead to drought declarations. However, if drought declarations are focused on Northern California conditions, as the historical analysis indicates, Southern California droughts may not be declared. This could have consequences for stakeholders in Southern California as conditions become dryer.

UPDATED GROUNDWATER ESTIMATES IN THE CENTRAL VALLEY (GOODRICH, CAYAN, PIERCE): A recently published study by Goodrich, Cayan and Pierce, examined how climate variability affects diversions (surface water that is unnaturally directed or transported to a different location) throughout California's Central Valley (CV), one of the most productive agricultural regions in the world. Using a historical record (1979-2010) of diversions from 531 sites, found that diversions are driven by different climate variables in the different regions of the CV. Southern CV surface water diversions responds to regional precipitation, wherein wet years result in the highest diversions (i.e. more surface water available for irrigation). In the northern CV, annual surface water diversions are more strongly governed by longer-term climate variability, and by competing demands from municipal and agricultural land uses. The results from this paper show that an initial estimate of diversions based on climate variables and land-use could be used to drive CV groundwater models to estimate groundwater. This supports CV water management by providing a more complete picture of water use in the CV prior to official diversion data made public (often with several years lag). Additionally, using these relationships could also support long-range water management planning under projections of increasing urban demand and likely more variable precipitation.

DATA SHARING NOTE: All the data that we have used for the product this year have come from publicly available data. CNAP has not produced any proprietary data this past year.



Publications with Highlights

Abatzoglou, J.T., B.J. Hatchett, P. Fox-Hughes, A.Gershunov, and N.J. Nauslar, 2020: Global climatology of downslope winds. *International Journal of Climatology*. DOI: 10.1002/joc.6607.

Aguilera, R., A. Gershunov, S.D. Ilango, J. Guzman Morales and T. Benmarhnia, 2019: Santa Ana winds of Southern California impact PM2.5 with and without smoke from wildfires. *GeoHealth*, 4, e2019GH000225. https://doi.org/10.1029/2019GH000225.

> Fine particulate matter (PM 2.5) raises human health concerns since it can deeply penetrate the respiratory system and enter the bloodstream, thus potentially impacting vital organs. Strong winds transport and disperse PM 2.5, which can travel over long distances. Smoke from wildfires is a major episodic and seasonal hazard in Southern California (SoCal), where the onset of Santa Ana winds (SAWs) in early fall before the first rains of winter is associated with the region's most damaging wildfires. However, SAWs also tend to improve visibility as they sweep haze particles from highly polluted areas far out to sea. Here we study the space-time relationship between daily levels of PM 2.5 in SoCal and SAWs spanning 1999–2012 and also further identify the impact of wildfire smoke on this relationship. SAWs tend to lower PM 2.5 levels, particularly along the coast and in urban areas, in the absence of wildfires upwind. On the other hand, SAWs markedly increase PM 2.5 in zip codes downwind of wildfires. These empirical relationships can be used to identify windows of vulnerability for public health and orient preventative measures.

Albano, C.M., M.D. Dettinger, and A.A. Harpold, 2020, Patterns and drivers of atmospheric river hydrologic variability across the western US, *Journal of Hydrometeorology*, 21, 17 p.,doi:10.1175/JHM-D-19-0119.1.

Albano, C. M., K.C. McGwire, M.B. Hausner, D. J. McEvoy, C. G. Morton, and J.L. Huntington, 2020, Drought Sensitivity and Trends of Riparian Vegetation Vigor in Nevada, USA (1985–2018). *Remote Sensing*, 12(9), 1362.

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Goddard, L. and A. Gershunov, 2020, Impact of El Niño on weather and climate extremes. *In El Niño Southern Oscillation in a Changing Climate* (eds M. J. McPhaden, A. Santoso, W. Cai), American Geophysical Union, In press.

Goodrich, J.P., D.R. Cayan, and D.W. Pierce, 2020, Climate and Land-Use Controls on Surface Water Diversions in the Central Valley, California, *San Francisco Estuary and Watershed Science*, 18 (1), https://doi.org/10.15447/sfews.2020v18iss1art2.

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Hatchett, B., Q. Cao, P. Dawson, C. Ellis, C. Hecht, B. Kawzenuk, J. Lancaster, T. Osborne, A. Wilson, M. Anderson, M.D. Dettinger, J. Kalansky, M. Kaplan, D. Lettenmaier, N. Oakley, F.M. Ralph, D. Reynolds, A. White, M. Sierks, and E. Sumargo, in review, Observation of an extreme atmospheric river storm with a diverse sensor network, *Earth and Space Science*, 30 p.

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Leibel S., M. Nguyen, W. Brick, J. Parker, S. Ilango, R. Aguilera, A. Gershunov, T. Benmarhnia, 2019, Increase in Pediatric Respiratory Visits Associated With Santa Ana Wind-driven Wildfire and PM 2.5 levels in San Diego County. *Annals of the American Thoracic Society*, doi: 10.1513/AnnalsATS.201902-150OC.

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Myers, M.R., D.R. Cayan, S.F. Iacobellis, J.M. Melack, R.E. Beighley, P.L. Barnard, et al 2019, Santa Barbara area coastal ecosystem vulnerability assessment, California Sea Grant, https://caseagrant.ucsd.edu/project/santa-barbara-area-coastal-ecosystem-vulnerability-assessment-sba-ceva.

The purpose of the Santa Barbara Area Coastal Ecosystem Vulnerability Assessment (SBA CEVA) is to help local coastal jurisdictions in southern Santa Barbara County better incorporate ecosystems into climate adaptation planning (Figure 1). This is accomplished using the best available scientific information from the work of leading climate, coastal hazard and shoreline change, watershed and ecological research programs. The long-term objective is to facilitate movement toward an ecosystem-based adaptation approach, which involves employing biodiversity and ecosystem services as part of a climate change adaptation strategy (SCBD AHTEG, 2009). Worldwide, ecosystem-based adaptation approaches have proved to be cost effective and broadly useful for addressing climate change (Munang et al., 2013). Coastal habitats buffer the impacts of storms and sea level rise while providing collateral benefits, such as clean air and scenic beauty, which contribute to people's health and enjoyment (Arkema et al., 2013). One step toward developing ecosystem based adaptation strategies is to determine potential vulnerabilities of ecosystems to projected climate change impacts; SBA CEVA does this. Our objective is to provide useful and accessible information for city and county planners and other local planners.

Myers, M.R., P.L. Barnard, E. Beighley, D.R. Cayan, J.E. Dugan, D. Feng, et al., 2019, A multidisciplinary coastal vulnerability assessment for local government focused on ecosystems, Santa Barbara area, California, *Ocean & Coastal Management* 182, https://doi.org/10.1016/j.ocecoaman.2019.104921.

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The destructive wildfires that occurred recently in the western US starkly foreshadow the possible future of forest ecosystems and human communities in the region. With increases in the area burned by severe wildfire in seasonally dry forests expected to result from climate change, judicious, science-based fire and restoration strategies will be essential for improving the resilience of forest ecosystems. We argue that fire use treatments (including prescribed fires and managed wildfires) as well as restoration thinning strategies, rather than conflicting with existing environmental objectives, will provide numerous co-benefits, including enhanced biodiversity, increased water availability, greater long-term and more sustainable carbon storage, improved forest resilience and adaptation to climate change, and reduced air pollution. Timber production, however, may have to be better aligned with fire management goals to achieve these co-benefits. Taking immediate actions today to promote positive ecological outcomes in seasonally dry forests should be a primary focus of management, particularly in the western US.

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Williams, E., C. Funk, S. Shukla, and D. McEvoy, 2020, Quantifying Human-Induced Temperature Impacts on the 2018 United States Four Corners Hydrologic and Agro-Pastoral Drought. *Bulletin of the American Meteorological Society*, 101(1), S11-S16.