Title:

WaterSMART: A platform for drought forecast in Intermountain West with the optimized multi-model ensemble approach

Applicant:
Utah State University
1415 Old Main Hill
Logan, UT 84322-1415

Project Manager:
Wei Zhang
4820 Old Main Hill
Logan, UT 84322-4820
w.zhang@usu.edu
435-797-1101

Table of Contents

Technical Proposal and Evaluation Criteria

Executive Summary

April 15, 2021
Applicant: Utah State University, Logan, Cache County, UT
PI: Wei Zhang co-I: Simon Wang, Yoshimitsu Chikamoto, Robert Gillies

Category B applicant
This project team is categorized as the Category B applicant (*universities*) partnering with Utah's state agencies (Category A). The partner agencies include Bear River Association of Governments, the Salt Lake City Department of Public Utilities, and the Utah Division of Water Resources. They express their keen interest in our drought forecast product and platform because future precipitation and temperature information is desired to make proactive plans. Moreover, team members of this project have collaborated previously with these agencies in other projects. These partner agencies committed in-kind contributions or provided their needs and interests to this project (see the letters of participation). Those partner agencies will contribute to this project by providing their information and knowledge to translate scientific outcomes into a user-friendly interface and format. Because of the broad applications in our project outcomes, potential partners in this project will include a wide range of agencies in the Intermountain West, such as water resources, land, agriculture, hydropower, and economy.

Project Summary:

Skillful drought forecast for its onset, demise, and intensity plays a crucial role for decision-makers and water resource managers in mitigation efforts. On March 17, 2021, Utah's governor declared a drought emergency when the vast majority of the state was in the 'moderate drought' category, and 90% experienced 'extreme drought' conditions. This drought was anticipated due to last year's La Niña, but predicting its drought intensity and duration requires seasonal climate forecasts. To continue the efforts in developing a reliable drought prediction several seasons ahead, we capitalize on the nation's North American Multi Ensemble (NMME) project, which provides climate forecasts up to 12 months earlier. The NMME forecasts exhibit coarse spatial resolution with many climate model outputs, thereby requiring a strategy for optimizing multiple members and a user-friendly web-based platform for stakeholders. The project team has developed a novel method (Bayesian updating) to optimize the NMME ensemble. This method enhanced the El Niño Southern Oscillation predictive skills for several seasons ahead while downscaling NMME forecasts from ~100 km to 4 km spatial resolution is directly applicable for resources management. This proposal will create a web-based platform for disseminating drought forecast products through the Utah Climate Center for water resource managers and planners across the Intermountain West.

Project length and completion date:
Two years from October 1, 2021, to September 30, 2023.

Federal facility:
The proposed project is not located in a Federal facility.

Technical Project Description and Milestones

Problem Statement

Reliable forecasts of drought conditions allow water resource managers, planners, and decision-makers to take proactive actions in mitigating drought impacts. The Intermountain West is a frequent victim of droughts. In March 2021, Utah's governor has declared a drought emergency across the state, emphasizing the broad impacts of this ongoing drought, and the current drought could continue through 2021.

There are not many options for the operational forecast when it comes to climate prediction, and the current seasonal forecasts rely mainly on the North American Multi-model Ensemble (NMME) products. The NMME encompasses dynamical seasonal forecasts produced by climate models developed in the United States and Canada. The NMME seasonal forecasts have played a crucial role in predicting the future states of meteorological variables that characterize droughts (e.g., precipitation and temperature). However, NMME forecasts exhibit several profound gaps in knowledge and performance that prohibit their appropriate use by stakeholders as a tool:

- First, the NMME model outputs are limited by low spatial resolution (i.e., 1 degree/80 miles) and systematic model biases, thereby restricting the capability of simulating and forecasting regional and local features of precipitation and temperature.
- Second, it is challenging to optimize the multi-model and multi-member products of the NMME forecast.
- Third, there is a gap between forecast outputs and a user-friendly platform to allow quick and intuitive access from management users.

To optimize the multi-model NMME products, the PI has developed a Bayesian updating method to optimize each member's weight and model (Zhang et al. 2017b). The Bayesian updating has proven capable of improving multi-model seasonal forecasts. Moreover, the members of this project team have developed web-based tools to disseminate the forecasts and further prospect of Utah water storage through Utah Climate Center (UCC) in our previous projects (the 2020 "WaterSMART: A platform toward an early warning system for shortages in Colorado River water supply" grant and the 2018 BoR WaterSMART "Synthesizing drought characteristics prediction to inform drought resilience decisions from days to years" grant) – illustrated next. These web-based tools have helped disseminate forecast outputs and meet the demands of users (e.g., water resource managers and planners).

Objective

This project's ultimate goal is to build a platform for skillful seasonal forecasts of precipitation and temperature by optimizing climate model outputs of the NMME project with the aid of statistical downscaling and Bayesian updating approaches. This project's cornerstone is a user-friendly web-based tool for drought prediction, which updates statistically-downscaled and

Bayesian-updating (BUSD) NMME products for 12 months ahead, providing helpful information for stakeholders and the general public. To accomplish this goal, we propose three main tasks:

Task 1: Statistical downscaling of NMME outputs by correcting the NMME products' biases and improving the spatial resolution from ~100 km to 4 km.

Task 2: Optimizing the forecast by conducting Bayesian updating to train the weights for the downscaled climate variables (i.e., precipitation and temperature) generated in Task 1 for each model and member.

Task 3: Developing a user-friendly web-based platform to disseminate Bayesian-updating products in real-time via the Utah Climate Center.

Scientific Background

Drought forecast

The Intermountain West exhibits highly complex hydrometeorological variability, modulated by atmospheric, oceanic, and torrential forcing (Wise 2012; Wang and Gillies 2012; Chikamoto et al. 2020). Tropical Pacific is an essential forcing for hydrological variability across the Intermountain West due to atmospheric teleconnections (Hoerling and Kumar 2002; Patricola et al. 2020). As crucial components of drought dynamics, skillful precipitation and temperature forecasts are essential to providing future drought information (e.g., seasons ahead). Fully-coupled climate models are major tools to produce dynamical drought forecasts (Yoon et al. 2012; Mo and Lyon 2015; Jia et al. 2015).

Some climate modeling centers provide operational seasonal forecasts (Murakami et al. 2016; Zhang et al. 2017a; Borovikov et al. 2019). Overall, seasonal climate predictability depends heavily on accurate initial conditions and model performance (e.g., model biases defined as differences between observations and model simulations). The NMME consists of multi-model seasonal forecasting systems, including fully-coupled global climate models from multiple modeling centers in the US and Canada at 1°×1° spatial resolution with their initialization approaches (Kirtman et al. 2014). The NMME products are the most reliable seasonal forecasts for precipitation and temperature as publicly available sources (Zhao et al. 2020; Zhang et al. 2017b; Kirtman et al. 2014). However, the current NMME products exhibit too coarse spatial resolution (~100-km) to assess local drought conditions, suffer from members in poor model performance, and are not a user-friendly web-based drought forecast tool. Statistical downscaling method and Bayesian updating can improve dynamical forecasting skills of the NMME product, which set the stage for meeting stakeholders' needs.

Statistical Downscaling

Statistical and dynamical downscaling technologies can generate high-resolution products that resolve regional and local characteristics (Kotamarthi et al. 2016; Hewitson and Crane 1996; Wilby and Wigley 1997; Kotamarthi et al. 2021; Abatzoglou and Brown 2012). However, the monthly NMME products are not suitable for dynamical downscaling because of the high

computational expense. On the other hand, statistical downscaling is a reasonable strategy to generate high-resolution NMME products that meet regional and local stakeholders' needs and requirements. Overall, there are four types of statistical downscaling approaches: direct transfer function, distributional mapping, spatial mapping, and weather generators (Lanzante et al. 2018; Maraun and Widmann 2018; Pierce et al. 2014). The spatial mapping method is suitable in this project, which seeks matching patterns between the past and the future projection. This method can implement statistical downscaling by building connections between observations and climate model outputs based on circulation changes (Vrac et al. 2007; Zhang and Villarini 2019; Villarini and Zhang 2020).

Bayesian updating

The NMME contains a wide variety of seasonal predictive skills and model performances but treats them with equal weight in each member and model. We can enhance the predictive skills by optimizing their weights based on their model performances. To optimize the NMME forecasts, the PI developed the Bayesian updating method for forecasting El Niño Southern Oscillation (ENSO) (Zhang et al. 2017b), which is the critical modulator of precipitation and temperature across the Intermountain West (Hoerling and Kumar 2002; Patricola et al. 2020). The Bayesian updating framework calculates each model's weight by implementing the Bayesian theorem to update the probability distribution of a variable (e.g., the Niño 3.4 index in NMME) with the new observed information (e.g., observation-based Niño 3.4 index). The Bayesian-updating predictions outperform the ENSO predictive skills in the equally-weighted model predictions for several seasons (Zhang et al. 2017b). Given the performance of Bayesian updating in optimizing the ENSO forecasts as a crucial modulator of precipitation and temperature in North America, this project applies the Bayesian updating to optimize NMME forecasts in the Intermountain West.

Planned Work

Based on the scientific background described above, we propose to produce the Bayesian updating and statistically-downscaled (BUSD) precipitation and temperature forecasts based on NMME to meet the needs of regional and local applications and develop a user-friendly web-based platform to disseminate the BUSD products.

Task 1: Statistical downscaling of NMME precipitation and temperature

This task proposes to use analog methods to statistically downscaling precipitation and temperature of the NMME project. We will use monthly Parameter-elevation Relationships on Independent Slopes Model (PRISM) data at 4-km spatial resolution (Daly et al. 1994) as the benchmark for training statistical downscaling against NMME-based precipitation and temperature. The spatial mapping approach provides the statistically-downscaled NMME precipitation and temperature with 4-km spatial resolution and bias correction based on the PRISM data. We will perform statistical downscaling by selecting seasonal forecasting products available from January 1982. We extract 76 ensemble members in six climate models from the

NMME project (Table 1). Based on preliminary results, the analog-based statistically-downscaled precipitation (4 km) averaged over 1982 exhibits improvements compared with original NMME products (~100 km) in terms of regional and local features of precipitation (Figure 1). This task will perform statistical downscaling for all selected members for each lead time.

Table 1 Climate model information used in this proposal.

Models	**Members**	**Lead Months**
CCSM4	10	0.5-11.5
CFSV2	28	0.5-11.5
CM2.1	10	0.5-11.5
FLORA06	12	0.5-11.5
FLORB01	12	0.5-11.5
NASA-GEOSS2S	4	0.5-11.5

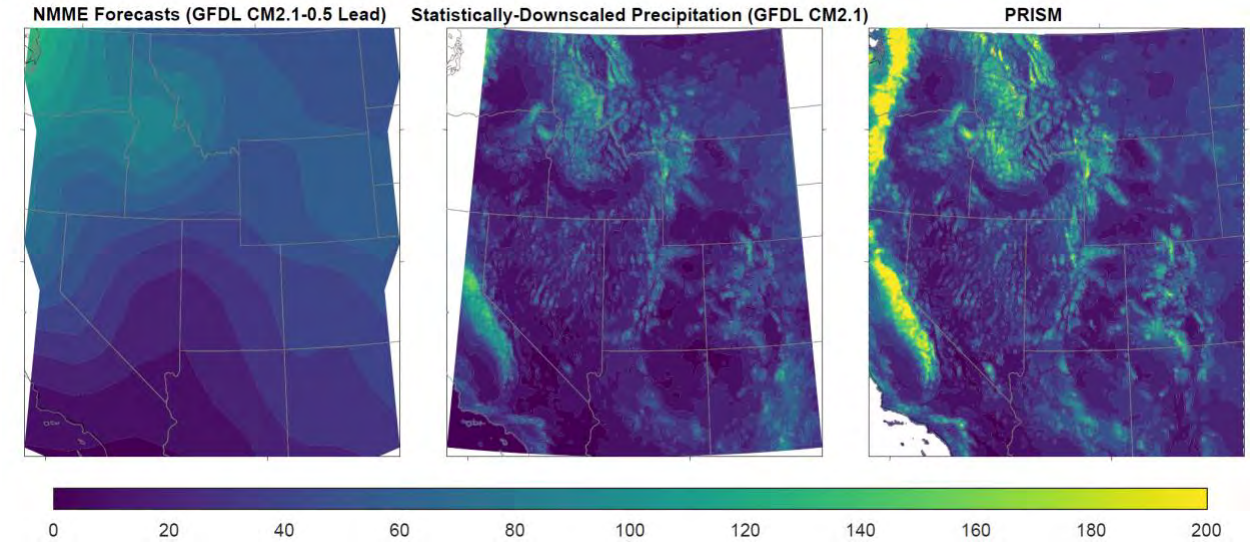

Figure 1 Annual average precipitation (1982) across the Intermountain West in an NMME model (GFDL CM2.1, Member 1), downscaled precipitation of GFDL CM2.1 (Member 1), and PRISM.

Task 2: Bayesian updating of statistically-downscaled NMME precipitation and temperature

This task will employ Bayesian updating to train each model/member's weight at each lead month by leveraging PRISM data and statistically downscaled NMME forecasts. The trained weights will apply to real-time seasonal forecasts by optimizing the combination of NMME forecasts.

The best estimates of the probability of different outcomes are defined by the climatology (i.e., the historical averages of the climate model forecasted variable (e.g., precipitation)), represented by the prior climatological density function $f(y)$. After a climate model forecast θ is available, the updated (or posterior) density function is given by Bayesian's theorem:

$$f(y|\theta) = \frac{f_\theta(\theta|y)f(y)}{f_\theta(\theta)} \quad (1)$$

where $f_\theta(\theta)$ is the unconditional density of θ, and $f_\theta(\theta|y)$ is the likelihood function. The posterior density $f(y|\theta)$ describes the conditional distribution of the variable given the climate model forecast θ and therefore represents a probability distribution forecast of the outcome. Here we apply Bayesian updating to a data sample, where [y_i, i=1… N] represents the historical observations of Y (PRISM data), i.e., a sample drawn from the prior density f(y). We represent a sample drawn from the posterior density $f(y|\theta)$ using the likelihood function $f_\theta(\theta|y)$. By definition, the likelihood function $f_\theta(\theta|y)$ is the distribution of a given model precipitation forecast (θ) (e.g., July 2010) conditioned on the observed precipitation (y) for the same month.

Using the likelihood function developed for each of the individual climate model members or the ensemble average of the six climate models, we assign a weight w_i to each observation y_i in the historical sample. The weight w_i represents the likelihood of observing outcome y_i given the climate forecast θ.

$$w_i = \frac{f_\theta(\theta|y_i)}{\sum_{j=1}^{N} f_\theta(\theta|y_j)} \quad (2)$$

where the sum of the weights w_i is equal to 1. The collection of the weights for all historical observations (e.g., the PRISM precipitation) is thus similar to a discrete probability distribution forecast for each model or model member. This suggests that the weights represent the likelihood of each discrete outcome given the climate model forecasts (e.g., N climate model forecasts). Weights of 1/N indicate that there is no potential skill and produce the same distribution as the prior distribution before Bayesian updating. The output is equivalent to a climatology forecast (i.e., the average historical conditions for the same months), and the member is automatically ignored. For models with a weak relationship between forecasts and observations, the Bayesian weights will be close to 1/N, indicating that each outcome is equally likely. For models with a strong and significant relationship between forecasts and observations, the Bayesian weights will be greater than 1/N and will grow as the potential skill increases, thereby assigning a large weight to the forecast. Any weights of less than 1/N indicate that the outcome is less likely than the climatology. The weights for every single model are combined to yield multi-model forecasts.

Using Bayesian updating, we produce the forecasts of the annual area-averaged precipitation across the Intermountain West (Figure 2) at the 0.5 lead month. The Bayesian updating can improve the skill with a higher correlation (correlation = 0.71) with the PRISM data than the multi-model ensemble average (i.e., equally-weighted; correlation = 0.65). This proposal will use Bayesian updating to produce seasonal forecasts of precipitation and temperature across the Intermountain West for all the lead months (i.e., 0.5-11.5). Note that the NMME outputs used for Bayesian updating (Figure 2) are not statistically downscaled, and the results that combine statistical downscaling and Bayesian updating will be even better than Figure 2, given the performance of statistical downscaling (Figure 1).

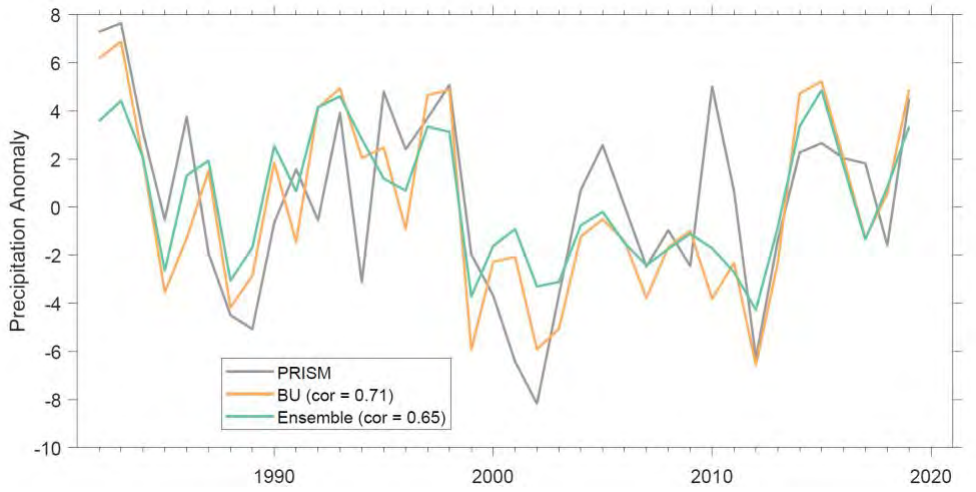

Figure 2 Time series of annual average precipitation across Intermountain West based on PRISM (station-based) data, multi-model ensemble average NNME forecasts (Ensemble), and Bayesian-updating (BU) NNME forecasts at the 0.5 lead month.

Task 3: Building a platform to disseminate the BUSD products through Utah Climate Center

This task will focus on building a user-friendly web-based platform to disseminate the BUSD precipitation and temperature forecasts through Utah Climate Center. This task is based on our previous and ongoing efforts and projects at Utah Climate Center to collect and disseminate climate information for stakeholders and the public. The BUSD precipitation and temperature will be updated every month. For example, Utah Climate Center has successfully developed web-based tools to disseminate forecasts for snowpack, evapotranspiration, streamflow, water storage, soil moisture at various time scales (e.g., daily, weekly and decadal scales) (Figure 3). Figure 3a exhibits soil moisture forecasts for a lead time of several days, which are disseminated on the website of the Utah Climate Center. The web-based platform will be equipped with a user-friendly interface and information, such as high, medium, or low precipitation and temperature, as well as educational content and professional use to provide a detailed perspective of seasonal forecasts. By communicating with water resource managers, planners, and decision-makers, this platform will be modified and updated based on their needs and feedback. The final product will be provided for water resource managers and the public through the Utah Climate Center.

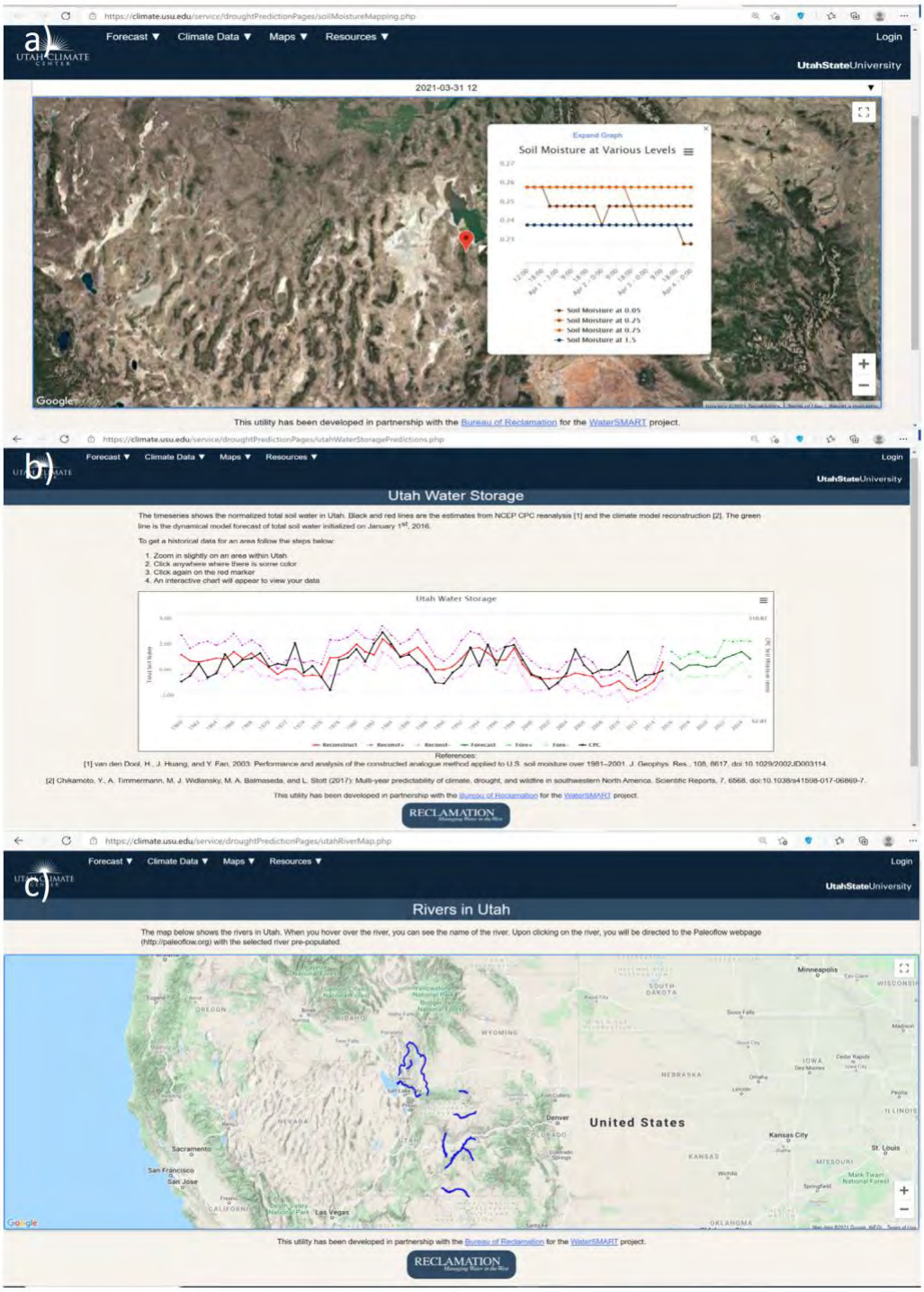

Figure 3 Forecasts of (a) Soil moisture at various levels, (b) Utah water storage (soil water), and (c) streamflow in Utah.

Planned Schedule

This project will accomplish three major tasks for two years (refer to Figure 4). During the first four quarters, this project will implement Task 1 that focuses on the statistical downscaling of NMME forecasts, and one manuscript will be drafted at the end of Year 1. This project will work on Bayesian updating of downscaled products from the 3rd quarter toward middle Year 2 when we will finish the second manuscript. Task 3 will be implemented from the beginning of Year 2 until the end of Year 2. We will develop a beta version webpage for the NMME products and communicate with stakeholders to provide comments and feedback for improvements. The final version of the web-based platform will be released and disseminated through the Utah Climate Center at the end of Year 2.

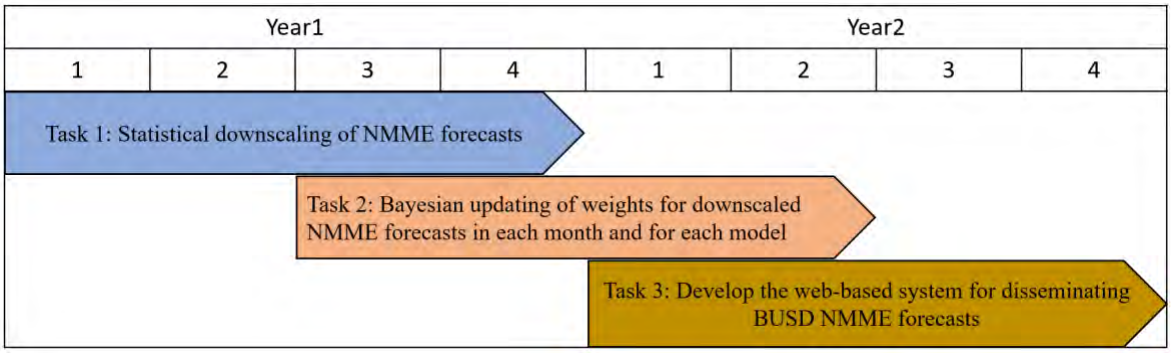

Figure 4 Project timeline with associated research tasks by quarter for the two project years.

Project Location

This project focuses on drought forecast across the Intermountain West. The map of the Intermountain West is obtained from the US Geological Survey (USGS).

Figure 5 Map of the Intermountain West (https://www.usgs.gov/media/images/map-intermountain-west).

Data Management Practices

The products of this project encompass a web-based platform, statistically-downscaled NMME forecasts, and Bayesian-updating statistically-downscaled forecasts. The Bayesian-updating statistically-downscaled forecast products generated by this project will be shared through Utah State University (USU) 's Institutional Repository (IR), which is a platform that supports open access initiatives and contributes to USU's intellectual output and engagement with global scholarly resources. The USU IR aims to archive and provide open access to the scholarly works, research, reports, publications, teaching materials, workshops, and lectures produced by USU faculty, staff, students, and organizations. In order to perform statistically-downscaling, we need to use observation-based precipitation and temperature (i.e., PRISM data), which are available on the webpage provided by Oregon State University.

Evaluation Criteria

Evaluation Criterion A - Benefits to Water Supply Reliability

Describe how your project will benefit water supply reliability:

A.1 Describe the water management issue(s) that your project will address. For example, will your project address water supply shortfalls or uncertainties, the need to meet competing demands for water, complications arising from drought, conflicts over water, or other water management issues? Describe the severity of the water management issues to be addressed through your project.

The seasonal precipitation amount is an essential water resource in the Intermountain West, and severe drought threat is a primary concern for water resource managers. The current ongoing drought damages the livelihood of numerous families and strained agricultural producers, industry, and even wildlife and recreation. To launch mitigation strategies and proactive management plans, water resource managers, planners, and decision-makers desire reliable precipitation and temperature forecasts several seasons beyond. However, the current dynamical forecasts cannot satisfy their needs because of coarse spatial resolution, model biases, and lack of strategy for optimizing multi-model forecasts and user-friendly forecast tools.

To meet the above needs, we aim to address the water management objectives included in this funding opportunity: water supply reliability, improved management of water deliveries, and drought management activities. The objectives will be achieved by improving or adapting forecasting tools and technologies to enhance the management of water supplies and reservoir operations. This funding opportunity states that "Reliable forecasts are an important water management tool that can be used to optimize operations and improve water management, manage risks, and inform water allocation strategies, or even water marketing." The drought forecast tool in this project can therefore help water resource managers provide reliable water supply and better management of water deliveries against drought. By applying statistical downscaling and Bayesian updating to the NMME forecasts for developing drought forecast tool, this project fits squarely

into "Projects to improve or adapt forecasting tools and technologies to enhance management of water supplies and reservoir operations" and "Projects can include the development or adaptation of forecasting tools to meet the needs of water managers. Projects may also include the adaptation of existing forecasts to better meet operational needs. Applicants are encouraged to explore whether there are existing data sets and forecast products that may be leveraged."

A.2 Explain how your project will address the water management issues identified in your response to the preceding bullet. In your response, please explain how your project will contribute to one or more of the following water management objectives and provide support for your response.

This project will develop a platform for drought forecast by improving or adapting forecasting tools and technologies. This platform will support water resource managers, planners, and decision-makers to provide reliable water supply and better management of water deliveries and drought. Therefore, this project will address three water management issues: water supply reliability, improved management of water deliveries, and drought management activities.

A.3 Describe to what extent your project will benefit one of the water management objectives listed in the preceding bullets. In other words, describe the significance or magnitude of the benefits of your project, either quantitatively or qualitatively, in meeting one or more of the listed objectives.

Readily accessible information – one with regional detail and without the need for expert translation – is a necessary tool for resources management. This project aims to develop a platform for drought forecast in the Intermountain West seasons ahead. The drought forecast will therefore help stakeholders (e.g., water resource managers, planners, and decision-makers) to launch mitigation strategies and proactive management plans that consist of deliveries, allocations, conservations, and efficient usages of operational water supply. This platform will benefit *water management objectives:* water supply reliability, improved management of water deliveries, and drought management activities.

A.4 Explain how your project complements other similar applications to the area where the project is located. Will your project complement or add value to other, similar efforts in the area rather than duplicate or complicate those efforts? Applicants should make a reasonable effort to explore and briefly describe related ongoing projects.

By combining statistical downscaling and Bayesian updating, this project will enhance and complement current efforts in the Intermountain West, such as the states of Utah, Colorado, Arizona, Nevada, California, Oregon, Idaho, and Wyoming. The project outcome will immediately benefit these states in terms of water resource management and disaster mitigation.

Evaluation Criteria B – Need for Project and Applicability of Project Results

Explain how your project will result in readily useful applied science tools that meet an existing need:

B.1. Will the project result in an applied science tool(s) or information that is readily applicable and highly likely to be used by water resource managers in the West?

As shown in Figure 3, prior WaterSMART projects and the Utah Climate Center have developed web-based tools for historical and future climate conditions with respect to snow, streamflow, precipitation, evaporation, and water storage. This project will lead to a web-based tool for drought forecast in the Intermountain West. The products of this project will be based on this established tool to provide reliable forecasts for resources managers to optimize operations and improve water management, manage risks, and inform water allocation strategies, or even water marketing.

B.1.a. Explain who has expressed the need and describe how and where the need for the project was identified (even if the applicant is the primary beneficiary of the project). For example, was the need identified as part of a prior water resources planning effort, determined through the course of normal operations, or raised by stakeholders? Provide support for your response (e.g., identify the entities that have expressed a need or cite planning or other documents expressing a need for the project).

As described in this funding opportunity announcement, reliable drought forecasts are essential to optimizing operations and improve water management, manage risks, and inform water allocation strategies, or even water marketing. To communicate with stakeholders (water resource managers, planners, and decision-makers), we collaborate with local organizations to address their needs for water resource planning and management. The local organizations expressing their needs include The Salt Lake City Department of Public Utilities, Bear River Association of Governments, and Utah Division of Water Resources.

- The Salt Lake City Department of Public Utilities is the oldest retail water provider in the West, committed to serving our customers and protecting our environment by delivering high-quality drinking water, managing flood control and stormwater, collecting and treating wastewater to standards that exceed Environmental Protection Agency (EPA) regulations, and maintaining and enhancing public street lighting. The Salt Lake City Department of Public Utilities actively protects our source waters in the Wasatch Canyons watershed and promotes conservation through efficient water use. They find that our project outcomes are helpful to promote efficient water use and make better plans for the future. They will participate in this project by providing their input and feedback in terms of the needs of water resource managers and explain how they perform planning based on the platform developed in this project. They committed to participating in this project with the amount of $8,000 as an in-kind contribution.
- Bear River Association of Governments is a voluntary organization of local governments created to facilitate intergovernmental cooperation and to ensure the orderly and harmonious coordination of federal, state, and local programs for the solution of mutual problems of the region. The goal of the Bear River Association of Governments is to serve as a multi-purpose organization, utilizing their combined total resources to provide a more effective means for planning and development of the physical, economic, and human resources of the region. They recognized that our project outcomes are beneficial to

planning and mitigating multi-year drought threats. They will participate in this project by providing their input and feedback in terms of the needs of planners and explain how they perform planning based on the platform developed in this project. They committed to participating in this project with the amount of $5,000 as an in-kind contribution.

- Utah Division of Water Resources is one of the seven divisions housed within the Department of Natural Resources. Tasked with Planning, Conserving, Developing, and Protecting Utah's water resources, the Division earnestly strives to be Utah's water steward. The Division recognizes the vitality in finding sustainable solutions to ensure Utah families have reliable water, that agriculture and businesses can be successful and that the environment can prosper. They need useful tools for water resource management and planning and strongly support the implementation of our project.

B.1.b. Will the results of your project inform water resource management actions and decisions immediately upon completion of the project, or will additionally work be required?

The results of this project will be used to inform water resource management actions and decisions immediately upon completion of the project. No additional work is required.

B.1.c. If applicable, will the results of your project be transferrable to other users and locations? Note: not all water management solutions are transferrable.

Yes, the results of this project apply mainly to drought forecast for many states in the Intermountain West. Because the platform is web-based, the project outcomes are accessible to the general public and transferable.

B.1.d. If the applicant is not the primary beneficiary of the project (e.g., Category B applicant), describe how the project beneficiaries have been or will be involved in planning and implementing the project?

The ultimate goal of this project is to establish a user-friendly web-based platform that distributes scientific outputs. To translate scientific outputs to a user-friendly tool, comments and feedback from the beneficiaries of this project are essential. This project will conduct surveys, hold a workshop and attend a meeting through the Utah Climate Center activities, which provide opportunities to involve the project beneficiaries.

Evaluation Criterion C — Project Implementation

C.1. Briefly describe and provide support for the approach and methodology that will be used to meet the objectives of the project.

Our web-based platform will disseminate statistically downscaled and Bayesian updated NMME forecasts (e.g., precipitation and temperature). The project team has extensive experience in downscaling methods and Bayesian updating, thereby providing a solid foundation to meet the objectives of this project. Moreover, the project team has developed web-based tools to

disseminate climate information through the webpage of Utah Climate Center, thanks to the financial support of the Bureau of Reclamation. The objective of this proposal is achieved through three major tasks:

Task 1: Statistical downscaling of NMME precipitation and temperature
Task 2: Bayesian updating of statistically-downscaled NMME precipitation and temperature
Task 3: Building a platform to disseminate the BUSD products through Utah Climate Center

C.2. Describe the work plan for the project. Include an estimated project schedule that shows the stages and duration of the proposed work, including major tasks, milestones, and dates.

The estimated timeline of this project is summarized in the task table below (Table 1). The project will organize a meeting and conduct surveys with stakeholders to obtain feedback and comments on the forecast products. At the end of Year 2, the platform of this project will be released online through the webpage of Utah Climate Center.

Table 1 Timeline of the tasks of this project

Tasks	Year1				Year2			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Task 1: Statistical downscaling of NMME precipitation and temperature	x	x	x	x				
Task 2: Bayesian updating of statistically-downscaled NMME precipitation and temperature			x	x	x	x		
Task 3: Building a platform to disseminate the BUSD products through Utah Climate Center					x	x	x	x

C.3. Provide a summary description of the products that are anticipated to result from the project. These may include data, metadata, digital or electronic products, reports, and publications. Note: using a table to list anticipated products is suggested.

The products of this project include statistically-downscaled NMME data, Bayesian-updated statistically-downscaled NMME data, and two peer-reviewed journal articles. The data products of this project will be shared through Utah Climate Center and will be freely accessible to the public.

C.4. Identify staff with appropriate credentials and experience and describe their qualifications. Describe the process and criteria that will be used to select appropriate staff members for any positions that have not yet been filled. Describe any plans to request additional technical assistance from Reclamation or via a contract. Please answer the following:

The project team includes well-qualified expertise on seasonal forecasts, downscaling approaches, Bayesian updating, and web-based system development. Our team members and specific roles are:

- Principal Investigator (PI): Dr. Wei Zhang (assistant professor at Utah State University) has expertise in seasonal prediction, statistical & dynamical downscaling, and dynamical modeling. He has developed several statistical-dynamical climate prediction schemes. He also developed the Bayesian updating method for the El Niño Southern Oscillation based on the NMME forecasts. He will direct the project and coordinate among different co-Is and associated tasks.
- Co-I: Dr. Yoshimitsu Chikamoto (assistant professor at Utah State University) has expertise in decadal climate prediction. He has published several high-impact papers that demonstrate the capability of earth system modeling to predict prolonged droughts in the southwestern US. He will work on evaluating the skill of seasonal predictions. He is leading a 2019 BOR WaterSMART project, "WaterSMART: A platform toward an early warning system for shortages in Colorado River water supply," and is involved in the 2018 BoR WaterSMART project "Synthesizing drought characteristics prediction to inform drought resilience decisions from days to years" as co-I.
- Co-I: Dr. S.-Y. Simon Wang (professor at Utah State University) has demonstrated expertise and productivity in climate dynamics and prediction, with experience in the dissemination of research results through the Utah Climate Center. He will assist with project tasks and build the web-based platform to disseminate project outcomes. He led two BoR projects in the past, with one ongoing project (see below).
- Co-I: Dr. Robert Gillies (professor at Utah State University and director of Utah Climate Center) has expertise in remote sensing and climate dynamics and will work with water agencies and planners to improve the seasonal forecast platform.
- Other personnel: one graduate student (TBD) to be named will pursue all tasks proposed by this project with supervision from the PI (Zhang) and co-I (Chikamoto, Wang, and Gillies).

C.4.a. Have the project team members accomplished projects similar in scope to the proposed project in the past either as a lead or team member?

Members of the project team were involved in previous and ongoing BoR WaterSMART projects that are similar in scope to the proposed project. Those projects are:

- the 2011 BoR WaterSMART "*Effective Assessments for Climate Uncertainties in Dynamical Downscaling over the Colorado Regions*" (Co-I: Wang).
- the 2013 BoR WaterSMART "*Building Decadal Prediction of Extreme Climate for Managing Water in the Intermountain West*" (PI: Wang).
- the 2018 BoR WaterSMART "*Synthesizing drought characteristics prediction to inform drought resilience decisions from days to years*" (PI: Wang, Co-I: Chikamoto).
- the 2019 BoR WaterSMART "*WaterSMART: A platform toward an early warning system for shortages in Colorado River water supply*" (PI: Chikamoto, Co-I: Wang).

C.4b. Is the project team capable of proceeding with tasks within the proposed project immediately upon entering into a financial assistance agreement? If not, please explain the reason for any anticipated delay.

Yes, the project team is capable of proceeding with tasks within the proposed project immediately upon entering into a financial assistance agreement.

Evaluation Criterion D — Dissemination of Results

D.1. Describe how the tools, frameworks, or analyses being developed will be disseminated, communicated, or made available to water resources managers who may be interested in the results.

D.1.a. If the applicant is the primary beneficiary of the project, explain how the project results will be communicated internally and to interested stakeholders and interested water resources managers in the area, if appropriate.

This does not apply to this project because the applicant is not the primary beneficiary. Please see the next answer.

D.1.b. If the applicant is not the primary beneficiary of the project (e.g., universities or research institutes), describe how project results will be communicated to project partners and interested water resources managers in the area.

The products of this project will be disseminated, communicated, and made available to stakeholders and the public through the project website on Utah Climate Center (https://climate.usu.edu) at Utah State University and in meetings webinars and workshops. The forecast products generated by this project will also be shared through Utah State University (USU) 's Institutional Repository (IR), which is a platform that supports open access initiatives and contributes to USU's intellectual output and engagement with global scholarly resources. The USU IR aims to archive and provide open access to the scholarly works, research, reports, publications, teaching materials, workshops, and lectures produced by USU faculty, staff, students, and organizations. In order to perform statistically-downscaling, we need to use observation-based precipitation and temperature (i.e., PRISM data), which are available on the webpage provided by Oregon State University. UCC routinely distributes climate information via extension activities along with interactions with the media channels. We will communicate the results to stakeholders on the basis of the existing service and outreach role. With more than 11,000 hits per month, the UCC data server will have no restrictions in using/placing the data on the UCC webpage. The data on the webpage will be freely accessible to the public. As the UCC director, co-I Gillies will be in charge of data archiving in this project. Through the UCC activities and past BoR projects, co-Is Wang and Gillies had hosted several meetings with the water agencies, first in 2011 and again in 2012, 2013, and 2016, to update water-climate research progress. This project plans to have a similar meeting to communicate with the water agencies. In addition to working directly with the agencies, we will present project results at scientific conferences and regional water user meetings, such as the annual Utah Water Users Workshop. Research results will also be published in peer-reviewed journals and a part of a thesis for the graduate student.

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Project Budget

Funding Plan and Letters of Funding Commitment

Table 1. Summary of non-Federal and Federal Funding Sources

Funding Sources	Funding Amount
Non-Federal Entities	
1. Utah State University*	$ 116,694.46
2. SLC Department of Public Utilities	$ 8, 000.00
3. Bear River Association of Governments	$ 5, 000.00
Non-Federal Subtotal:	$129,694.46
Other Federal Entities	None
Requested Reclamation Funding:	$ 129,675.40
Total Project Funding:	$ 259,369.86

USU's contribution to the cost-share requirement will include waived indirect costs on the contribution by USU. The USU's contribution also includes partial faculty support for the project members, and the assistantship, tuition, health insurance and fringe benefits for the graduate student.

Funding partners and the types of contributions committed per the attached letters and Third Party Sharing Commitment Forms are:

- SLC Department of Public Utilities
- Bear River Association of Governments

In the following pages are included letters of funding commitment from the two collaborating agencies. If more detailed letters of commitment than the following are requested, they will be supplied within two weeks of notice of award.

OFFICE OF RESEARCH
UtahStateUniversity.

Sponsored Programs

THIRD PARTY COST SHARING COMMITMENT FORM

Project Title: WaterSMART:A platform for drought forecast in Intermountain
Project Period: From October 1 2021 to September 30 2023
USU PI/PD: Wei Zhang
Contributing Organization: Bear River Association of Governments

Proposed Cost Share

Personnel (salary, wages, & fringe benefits):	$ 5,000.00
Travel:	
Supplies:	
Capital Equipment (Over $5000):	
Other:	
Indirect Cost:	
Total Contribution:	$ 5,000.00

Description of "Other" budget items: _____

An auditable record of the above contribution to USU will be provided as required by the Prime Award and Uniform Guidance, Title 2, Subtitle A, Chapter II, Part 200, Subpart D, § 200.306 Cost sharing or matching, as applicable for the duration of the project.

USU and your organization, by virtue of your in-kind support, are subject to the Uniform Guidance Title 2, Subtitle A, Chapter II, Part 200, Subpart D, § 200.306 Cost sharing or matching: https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=42ca0bc21c09b15826e1d166d3c9cc92&mc=true&n=sp2.1.200.d&r=SUBPART&ty=HTML#se2.1.200_1306. In reviewing this section, you will note that all contributions, including your portion, will be accepted as part of the cost sharing or matching when the contributions meet all of the following criteria:

1. Are verifiable from the non-Federal entity's records;
2. Are not included as contributions for any other Federal award;
3. Are necessary and reasonable for accomplishment of project or program objectives;
4. Are allowable under Subpart E—Cost Principles of this part;
5. Are not paid by the Federal Government under another Federal award, except where the Federal statute authorizing a program specifically provides that Federal funds made available for such program can be applied to matching or cost sharing requirements of other Federal programs;
6. Are provided for in the approved budget when required by the Federal awarding agency; and
7. Conform to other provisions of this part, as applicable.
8. Costs may only be incurred during the project period of performance.
9. The basis for determining the valuation of the personnel service, material, equipment, building and land must be documented.

Contributor: _____ Date: 4/1/21

Typed Name & Title: Zac Covington, Sr. Regional Planner (BRAG)

As USU PI/PD, I certify that the proposed cost share:

1. Is necessary and reasonable for the efficient accomplishment of the specified project; and
2. Is allowable under the applicable cost principles and other terms and conditions of the award or program.

USU PI: Wei Zhang Date: March 31 2021

Revised: 03/31/2017
Second Revision: 08/2019

OFFICE OF RESEARCH
UtahStateUniversity.

Sponsored Programs

THIRD PARTY COST SHARING COMMITMENT FORM

Project Title:	WaterSMART:A platform for drought forecast in Intermountain West
Project Period:	From October 1 2021 to September 30 2023
USU PI/PD:	Wei Zhang
Contributing Organization:	Salt Lake City Department of Public Utilities

Proposed Cost Share

Personnel (salary, wages, & fringe benefits):	$ 8,000.00
Travel:	
Supplies:	
Capital Equipment (Over $5000):	
Other:	
Indirect Cost:	
Total Contribution:	$ 8,000.00

Description of "Other" budget items: Potential data from SLC & long-term data set of Streamflow.

An auditable record of the above contribution to USU will be provided as required by the Prime Award and Uniform Guidance, Title 2, Subtitle A, Chapter II, Part 200, Subpart D, § 200.306 Cost sharing or matching, as applicable for the duration of the project.

USU and your organization, by virtue of your in-kind support, are subject to the Uniform Guidance Title 2, Subtitle A, Chapter II, Part 200, Subpart D, § 200.306 Cost sharing or matching: https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=42ca0bc21c09b15826e1d166d3c9cc92&mc=true&n=sp2.1.200.d&r=SUBPART&ty=HTML#se2.1.200_1306. In reviewing this section, you will note that all contributions, including your portion, will be accepted as part of the cost sharing or matching when the contributions meet all of the following criteria:

1. Are verifiable from the non-Federal entity's records;
2. Are not included as contributions for any other Federal award;
3. Are necessary and reasonable for accomplishment of project or program objectives;
4. Are allowable under Subpart E—Cost Principles of this part;
5. Are not paid by the Federal Government under another Federal award, except where the Federal statute authorizing a program specifically provides that Federal funds made available for such program can be applied to matching or cost sharing requirements of other Federal programs;
6. Are provided for in the approved budget when required by the Federal awarding agency; and
7. Conform to other provisions of this part, as applicable.
8. Costs may only be incurred during the project period of performance.
9. The basis for determining the valuation of the personnel service, material, equipment, building and land must be documented.

Contributor: Travis Kirkham Date: 4/6/2021

Typed Name & Title:

As USU PI/PD, I certify that the proposed cost share:

1. Is necessary and reasonable for the efficient accomplishment of the specified project; and
2. Is allowable under the applicable cost principles and other terms and conditions of the award or program.

USU PI: Wei Zhang Date: March 31 2021

Revised: 03/31/2017
Second Revision: 08/2019

Budget of Proposal

White, blue and green shades indicate federal, applicant, and third-party funding in the table below.

Table 2 Funding Sources

Funding Sources	Percent of Total Project Cost	Total Cost by Source
Reclamation Funding	50.00%	$129,675.40
Applicant Funding	44.99%	$116,694.46
Third Party Funding	5.01%	$ 13,000.00
Totals	100%	$259,369.86

Table 3. Budget Proposal

Budget Item Description	$/Unit	Quantity	Type	Total Cost
Key Personnel Salaries/Wages				**$75,251.38**
Wei Zhang, Y1	92,689.96	4.48%	year	$4,152.51
Wei Zhang, Y1	92,689.96	3.85%	year	$3,568.57
Wei Zhang, Y2	95,470.76	4.48%	year	$4,277.09
Wei Zhang, Y2	95,470.91	3.85%	year	$3,675.63
Yoshimitsu Chikamoto, Y1	94,099.11	4.48%	year	$4,215.64
Yoshimitsu Chikamoto, Y1	94,099.11	3.85%	year	$3,622.82
Yoshimitsu Chikamoto, Y2	96,922.10	4.48%	year	$4,342.11
Yoshimitsu Chikamoto, Y2	96,922.10	3.85%	year	$3,731.50
Robert Gillies, Y1	138,915.84	3.85%	year	$5,348.26
Robert Gillies, Y1	138,915.84	1.925%	year	$2,667.19
Robert Gillies, Y2	143,083.38	3.85%	year	$5,508.71
Robert Gillies, Y2	143,083.38	1.925%	year	$2,747.20
Simon Wang, Y1	162,000.67	4.48%	year	$7,257.63
Simon Wang, Y1	162,000.67	3.85%	year	$6,237.03
Simon Wang, Y2	166,860.71	4.48%	year	$7,475.36
Simon Wang, Y2	166,860.71	3.85%	year	$6,424.13
Total request	Y1 $20,974.04	Y2 $21,603.27		$42,577.31
Total match	Y1 $16,095.61	Y2 $16,578.46		$32,674.07
Other Personnel Salaries/Wages				**$40,000.00**
Graduate Student TBN Y1	20,000	25%	year	$ 5,000.00
Graduate Student TBN Y1	20,000	75%	year	$15,000.00
Graduate Student TBN Y2	20,000	25%	year	$ 5,000.00
Graduate Student TBN Y2	20,000	75%	year	$15,000.00
Total request	Y1 $5,000	Y2 $5,000		$10,000.00
Total match	Y1 $15,000	Y2 $15,000		$30,000.00
Fringe Benefits				**$36,348.98**
Wei Zhang, Y1	4,152.51	46.6279%	Salary dollar	$1,936.22
Wei Zhang, Y1	3,568.57	46.6279%	Salary dollar	$1,663.94
Wei Zhang, Y2	4,277.09	47.1278%	Salary dollar	$2,015.70
Wei Zhang, Y2	3,675.63	47.1278%	Salary dollar	$1,732.24
Yoshimitsu Chikamoto, Y1	4,215.64	46.6279%	Salary dollar	$1,965.66
Yoshimitsu Chikamoto, Y1	3,622.82	46.6279%	Salary dollar	$1,689.24
Yoshimitsu Chikamoto, Y2	4,342.11	47.1278%	Salary dollar	$2,046.34
Yoshimitsu Chikamoto, Y2	3,731.50	47.1278%	Salary dollar	$1,758.57
Robert Gillies, Y1	5,348.26	46.6279%	Salary dollar	$2,493.78
Robert Gillies, Y1	2,667.19	46.6279%	Salary dollar	$1,243.65
Robert Gillies, Y2	5,508.71	47.1278%	Salary dollar	$2,596.14
Robert Gillies, Y2	2,747.20	47.1278%	Salary dollar	$1,294.69
Simon Wang, Y1	7,257.63	46.6279%	Salary dollar	$3,384.08
Simon Wang, Y1	6,237.03	46.6279%	Salary dollar	$2,908.20
Simon Wang, Y2	7,475.36	47.1278%	Salary dollar	$3,522.98
Simon Wang, Y2	6,424.13	47.1278%	Salary dollar	$3,027.01

Graduate Student TBN Y1	5,000.00	2.678%	Salary dollar	$ 133.75
Graduate Student TBN Y1	15,000.00	2.678%	Salary dollar	$ 401.25
Graduate Student TBN Y2	5,000.00	2.678%	Salary dollar	$ 133.75
Graduate Student TBN Y2	15,000.00	2.678%	Salary dollar	$ 401.25
Total request	Y1 $9,913.49	Y2 $10,314.91		$20,228.41
Total match	Y1 $7,906.28	Y2 $8,213.75		$16,120.03
Travel	$2,480	2 (1/year)	Trip	**$4,960**
Equipment				0
Materials & Supplies				0
Contractual				0
Third Party In-Kind Contributions				**$13,000.00**
SLC Department of Public Utilities				
Salary/benefits	$4000	2	Year	$8,000.00
Bear River Association of Governments				
Salary/benefits	$2500	2	Year	$5,000.00
Environmental Regulatory Compliance Costs				**$ 0**
Other Expenses				**$ 15,706.87**
Tuition and fees Y1	$5,451.00	1	Year	$5,451.00
Tuition and fees Y2	$5,723.55	1	Year	$5,723.55
Graduate student health insurance Y1	$2,179.00	75%	Year	$ 1,634.25
Graduate student health insurance Y1	$2,179.00	25%	Year	$ 544.75
Graduate student health insurance Y2	$2,179.00	75%	Year	$ 1,764.99
Graduate student health insurance Y2	$2,353.32	25%	Year	$ 588.33
Publication Fee				
Reporting Costs				
TOTAL DIRECT COST				**$185,266.69**
TDC Federal Funding				$ 92,339.51
TDC USU Cost Share				$ 79,927.18
TDC Third Party In-Kind				$ 13,000.00
INDIRECT COSTS	$ 0.46	158,132.68	MTDC Dollar	**$74,103.17**
IDC on Federal Funding @ 46% MTDC	0.46	$ 78,938.80	MTDC	$37,335.89
Cost shared IDC on USU TDC	0.46	$ 79,927.18	MTDC	$36,767.28
IDC on Third Party In-Kind	$ 0			$ 0.00
Total Federal Funds Requested				**$129,675.40**

USU Cost Share Committed				$116,694.46
Third Party Cost Share Committed				$ 13,000.00
Total Estimated Project Costs				**$259,369.86**

Budget Narrative

1. **Salaries and Wages: $115,251.38 ($52,577.31 Federal funding; $62,674.07 cost share)**

All labor rates proposed represent actual labor rates of the identified personnel with anticipated 3% annual increase for faculty.

A. **Key Personnel Salary: $75,251.38 ($42,577.31 Federal funding; $32,674.07 cost share)**

- PI/Program Manager Dr. Zhang requests 1-month salary/year (8.33% effort/year) for a total of $15,673.80 request funding with $7,244.20 cost share. Dr. Zhang will direct the project and mentor a graduate student to accomplish associated tasks and dissemination of project outputs.
- Co-Investigator Dr. Chikamoto requests 1-month salary/year (8.33% effort/year) for a total of $15,912.07 request funding with $7,354.32 cost share. Dr. Chikamoto will work on evaluating the skill of seasonal predictions.
- Co-Investigator Dr. Wang requests 1-month salary/year (8.33% effort/year) for a total of $27,394.15 funding with $12,661.16 cost share. Dr. Wang will assist with project tasks and build the web-based platform to disseminate project outcomes.
- Co-Investigator Dr. Gillies requests three-week salary/year (5.8% effort/year) for a total of $16,271.36 funding with $5,414.39 cost share. Dr. Gillies will work with water agencies and planners to improve the seasonal forecast platform.

B. Other Personnel Salary: $ 40,000.00 ($10,000.00 Federal funding; $30,000.00 cost share)

- One graduate student to be named for 12 months of research assistantship per year at $1,666.66 per month for Y1 and Y2, with a total of $40,000 request funding and $30,000 cost share. Graduate student will pursue all tasks proposed by this project with supervision from the PI (Zhang) and co-I (Chikamoto, Wang, and Gillies).

2. **Fringe Benefits: $36,348.98 ($20,228.41 Federal Funding; $16,120.03 cost share)**

- Fringe benefits are charged at 46.5% for FY2022 (47.0% for FY2023) for faculty, 8.3% for student summer months and 0.8% student academic year. These are USU's proposal preparation benefit rates and for faculty and staff they cover Social Security, retirement, insurance, unemployment, disability, and Worker's Compensation costs. The total fringe benefits are $36,348.98 with $16,120.03 cost share.

3. **Travel Costs: $4,960.00 ($4,960.00 Federal Funding; $0 cost share)**

- Domestic travel costs are included for one trip per year for PI Zhang or other project members to present results at the American Geophysical Union Fall Meeting, the

American Meteorological Society meeting, or the Utah Water Users Workshop. Each 5-day trip is budgeted at $2,480 to cover conference registration ($500), abstract fees ($65), airfare and ground transportation ($730), hotel (4 nights at $250), and per diem (4 days at $46). The total cost for each year is $2,480, and total cost of $4,960.

4. **Equipment: None**

5. **Materials, Supplies and Consumables**

6. **Contractual: None**

7. **Collaborating Organizations: $13,000.00 ($0 Federal funding; $13,000 cost share)**

   A. Salt Lake City Department of Public Utilities: $8,000.00 ($0 Federal Funds, $8,000 cost share)
      Water Resources Scientist, $8,000 ($100/hour, total 80 hours in Year 1 & Year 2)
   B. Bear River Association of Governments: $5,000.00 ($0 Federal Funds, $5,000 cost share)
      Water resource planner: $5000 ($100/hour, total 50 hours in Year 1 & Year 2)

8. **Environmental Regulatory Compliance Costs: none required**

9. **Other Expenses: $15,706.87 ($14,573.79 Federal funding; $1,133.08 cost share)**
   A cost is requested to pay for tuition fee and health insurance for Year 1 & Year 2, with a total of $15,706.87 request funding and $1,133.08 cost share.

10. **Direct costs: $185,266.69 ($ 92,339.51 Federal funds; $79,927.18 USU cost share, $13,000.00 Third Party In-kind Cost Share)**

11. **Indirect costs: $74,103.17 ($37,335.89 Federal funds; $36,767.28 USU cost share)**

12. **Federal Funding Requested: $129,675.40**

13. **Total Cost Share Committed: $129,694.46**

14. **Total Project Cost: $259,369.86**

Environmental and Cultural Resources Compliance

Overall, this is not applicable to our project because our project mainly aims to provide information based on statistical modeling and analyses. The following is more detailed answers for each question.

• Will the proposed project impact the surrounding environment?

No. This project has no direct impact on the surrounding environment because this project consists of analyzing data that is already available on the public.

• Are you aware of any species listed or proposed to be listed as a Federal threatened or endangered species, or designated critical habitat in the project area?

This project has no direct impact on any species because main tasks in this project is data analysis. However, the upcoming drought information provided in this project may be helpful to protect species as a result of the proactive management by the state agencies.

• Are there wetlands or other surface waters inside the project boundaries that potentially fall under CWA jurisdiction as "Waters of the United States?"

This is not applicable to our project because this project proposes no constructions and assessments associated with clear water.

• When was the water delivery system constructed?

This is not applicable to this project because we have no construction plan of water delivery system.

• Will the proposed project result in any modification of or effects to, individual features of an irrigation system?

No, this project has no irrigation system.

• Are any buildings, structures, or features in the irrigation district listed or eligible for listing on the National Register of Historic Places?

This is not applicable to this project because our project has no buildings, structures, and features in the irrigation district.

• Are there any known archeological sites in the proposed project area?

Although our project area covers the Intermountain West, this project has no impact on archeological sites because our project uses open datasets.

• Will the proposed project have a disproportionately high and adverse effect on low income or minority populations?

No, this project has no impact on low income or minority populations.

• Will the proposed project limit access to and ceremonial use of Indian sacred sites or

result in other impacts on tribal lands?

No, this project has no impact on Indian sacred sites and tribal lands.

• **Will the proposed project contribute to the introduction, continued existence, or spread of noxious weeds or non-native invasive species known to occur in the area?**

No, this project won't contribute to the introduction, continued existence, spread of noxious weeds, and non-native invasive species.

Required Permits or Approvals

Not applicable.

Letter of Participation and Support

This proposal includes four letters of participation as follows:

- Bear River Association of Governments
- Salt Lake City Department of Public Utilities
- Utah Division of Water Resources

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BEAR RIVER ASSOCIATION OF GOVERNMENTS
170 N. Main, Logan, Utah 84321 ♦ (435) 752-7242 ♦ Fax (435) 752-6962 ♦ www.brag.utah.gov

April 1, 2021

Wei Zhang
Assistant Professor of Climate
Department of Plants, Soils, and Climate
Utah State University
4820 Old Main Hill
Logan, UT84322-4820

Re: WaterSMART Seasonal Prediction Grant

Dear Dr. Zhang,

This is a letter of support for the propspective project proposal from the USU Department of Plant's, Soils, and Climate titled, "WaterSMART: A platform for drought forecast in Intermountain West with the optimized multi-model ensemble approach." This project will require water and other professional planner inputs to develop a platform of seasonal climate forecasts. We believe that this project will develop a useful tool for producing and disseminating seasonal forecasts of precipitation and temperature across the Intermountain West, which includes the Bear River Region of northern Utah.

With this letter, we commit to provide $5,000 of in-kind contributions for use as a partial match to the federal Bureau of Reclamation request, beginning on the date when the project is funded for the project duration. It includes costs such as staff salaries, fringe benefits, information regarding the needs of ours and other organizations, and other communications as needed (personnel at $100/hour rate with up to 25 hours for each year). There are no other contingencies associated with this funding commitment.

We are excited to be involved in this planning process. Please let me know if you have any questions by contacting me at zacc@brag.utah.gov, or 435-713-1423.

Sincerely,

Zac Covington
Sr. Regional Planner

April 6, 2021

Wei Zhang

Assistant Professor of Climate
Department of Plants, Soils, and Climate
Utah State University
4820 Old Main Hill
Logan, UT84322-4820

Re: WaterSMART Seasonal Prediction Grant

Dear Dr. Zhang,

This letter is a commitment from Salt Lake City Department of Public Utilities to support the perspective project proposal, "***WaterSMART: A platform for drought forecast in Intermountain West with the optimized multi-model ensemble approach***". This project is based on a team of researchers from Utah State University and requires water planner inputs to develop a platform of seasonal climate forecasts. We believe that this project will develop a useful tool for producing and disseminating seasonal forecasts of precipitation and temperature across the Intermountain West.

We will provide $8,000 of in-kind contributions for use as a partial match to the federal Bureau of Reclamation request, beginning on the date when the project is funded for the project duration. It includes costs such as staff salaries, fringe benefits, information regarding needs of water agency, and other communications (personnel in $160/hour rate with 25 hours for each year). There are no other contingencies associated with this funding commitment.

Sincerely,

Tracie Kirkham
Water Resources Scientist

cc: Tamara Prue

SPENCER J. COX
Governor
DEIDRE HENDERSON
Lieutenant Governor

State of Utah
DEPARTMENT OF NATURAL RESOURCES
BRIAN C. STEED
Executive Director
Division of Water Resources
Todd D. Adams
Division Director

April 8, 2021

Wei Zhang
Utah State University
4820 Old Main Hill
Logan, UT 84322-4820

RE: Letter of Support for Research Proposal on Seasonal Drought Forecasting in Intermountain West

Wei Zhang:

The Utah Division of Water Resources understands that you are seeking federal funds to create a platform for seasonal drought forecasting in the Intermountain West using an optimized multi-model ensemble approach. Furthermore, we are encouraged that your initial research has yielded promising results in enhancing forecasting abilities.

As an agency, our mission is to plan, conserve, develop and protect Utah's water resources. Your research to improve seasonal drought forecasting has the potential to help decision makers and water resources managers throughout the region to mitigate climate-driven natural disasters. Therefore, the Utah Division of Water Resources wishes to express its support of your research proposal and hopes that you are successful in obtaining the desired federal funding.

Sincerely,

Todd Stonely

Todd Stonely, P.E.
Assistant Director

cc: Robert Gillies
Yoshimitsu Chikamoto
S.-Y. Simon Wang

1594 West North Temple, Suite 310, PO Box 146201, Salt Lake City, UT 84114-6201
telephone (801) 538-7230 • facsimile (801) 538-7279 • TTY (801) 538-7458 • *www.water.utah.gov*

OFFICIAL RESOLUTION

April 16, 2021
Refer to: DP# 8961

US Dept of Int. –Bureau of Reclamation
Denver, Colorado

RE: "WaterSMART: A platform for drought forecast in Intermountain West with the optimized multi-model ensemble approach"

Greetings:

Utah State University (USU) is pleased to submit the above referenced proposal for your consideration and review.

This proposal has been reviewed by Sponsored Programs administration to verify that it meets all necessary criteria and addresses all required compliance issues and is supported for submission. Furthermore, if the proposal is awarded, USU agrees to work with Reclamation to meet established deadlines and to perform the statement of work as outlined in the proposal with the budgetary limits imposed and within the designated period of performance. We are requesting $129,675.40 to support the proposed statement of work for the period of performance of October 1, 2021 to September 30, 2023. I certify the capability of USU to provide the in-kind contributions specified in the funding plan.

Established in 1888, USU (Utah's sole land-grant institution) is a state-owned, non-profit institution of higher education. As such, USU requests that any resulting award from this proposal incorporate terms and conditions applicable to its required adherence to Title 2 of the Code of Federal Regulations, as well as its need to comply with the laws of the State of Utah.

I certify that I am an Authorizing Official for USU with legal authority to enter into an agreement and the office is responsible for contractual matters. The USU principal investigator for the proposed project will be Dr. Wei Zhang.

Please send all contractual and/or administrative correspondence, including all award and/or modification documents requiring signature to: Devin Hansen, Utah State University, Sponsored Programs, 1415 Old Main Hill – Room 64, Logan, UT 84322-1415, (435) 797-9153, devin.hansen@usu.edu. I can also be contacted at connor.idso@usu.edu or by phone at (435) 797-0943.

Please feel free to direct questions of a technical nature or regarding the statement of work to Dr. Zhang at (435) 797-1101.

Sincerely,

Connor Idso

Connor Idso
Grant & Contract Officer
Utah State University