Roadmap for a Climate Resilient Forecasting Framework

Introduction

Climate change is altering the timing, pace, and scale of the weather events that provide precipitation to California during the wet season from October through April. Historically, 90% of the annual precipitation shows up during this time with 50% showing up in the 3-month window from December through February. Snowpack is built up in the Sierra Nevada and Southern Cascade mountains from December through March, with a peak water content on or around April 1. Melting of the snowpack provides a key component of California's water supply and typically occurs from April through July.

As the world warms, it is expected that in future decades, on average, there will be fewer but stronger storms during the wet season, a smaller snowpack limited to higher elevations, and warmer periods between storms that will act to dry out the landscape. The past decade has demonstrated that the historical patterns that are the foundation of current forecasting methods are already changing with new extremes (both wet and dry) that impact forecast quality using the methods that have been in place for decades.

Adapting to climate change requires changing the way we observe and forecast weather and hydrologic conditions. Historical patterns and relationships between precipitation, snowpack, and streamflow that have been used to anticipate how much water will run off for beneficial use have already shown vulnerabilities as illustrated in water year 2021. While DWR's observation and forecasting programs have a long history of partnerships with the research community to bring relevant research advances into program operation, the pace and scale of extremes necessitate acceleration of recent and ongoing advances to ensure a forecasting framework that can adapt at the pace of a changing climate. This document provides a roadmap for a climate resilient forecasting framework (hereafter referred to as the Roadmap) to adapt to changing conditions.

Continuing the Collaboration

DWR works with numerous agencies and academic partners who can help develop and deliver products that contribute to the climate resilient forecasting framework. Even after the initial framework is established, continued change in climate and ongoing development in technologies will necessitate staying connected to the research community to effectively transfer advances that are ready for program implementation. This is referred to as the Research to Operations Partnership (REOP) initiated as part of the Atmospheric River Research Program led by the State Climatologist and Scripps Institution of Oceanography's Center for Western Weather and Water Extremes (CW3E). An assessment of the climate resilient forecasting framework should be conducted regularly to reflect ongoing advancements and further climate change. The active collaboration with the research community supports a thorough peer-review process through peer participation in product development, the use of peer-reviewed scientific publications, and expert elicitation panels to evaluate product implementation as part of the framework.

Goals

The California Cooperative Snow Surveys, which DWR leads, has been working with the research community including NOAA, NASA, NCAR, the USGS and the University of California for more than a decade. Building upon those collaborations, DWR has developed a framework for climate resilient forecasting that focuses on two goals.

1. Transition from index-based statistical forecasting tools, such as linear regression of precipitation, snowpack, and runoff indices, to spatially explicit, physically based, and climate informed modeling tools such as watershed models that simulate the physical processes of snow accumulation and melt and can incorporate forecasts.

2. Create an integrated forecast platform that allows easier visual inspection of observed conditions and a customizable decision support dashboard that connects observations, high resolution near-term forecasting, standard weather forecasting, 2 to 4 week outlooks, sub-seasonal to seasonal outlooks, and water year outlooks.

Achieving these goals will require financial investment, personnel augmentation, and technical advances in three main areas: observing systems, forecasting tools, and decision support capabilities. This Roadmap identifies fourteen objectives that enable the goals to be reached. It will be updated and refined as needed as work and climate change continue to progress.

Climate Resilient Forecasting Framework Development Objectives

Fourteen objectives have been identified across observations (4), forecasting tools (5) and decision support capabilities (5) to enable the climate resilient forecasting framework. The fourteen objectives to achieve the two goals are:

Observation Objectives:

1) Upgrade and replace the current Statewide Monitoring Network (SMN) station infrastructure and instrumentation to ensure reliable collection of a greater variety of hydroclimate data as illustrated in Figure 1. These new Hydrometeorological Data Acquisition System (HyDAS) stations will improve data quality, metric monitoring, and support a more operationally efficient network.
2) Current SMN laboratory facilities need to be replaced with a centralized location to enable staff to test, calibrate, fabricate, and store equipment before deployment in the field to build, operate and maintain the next generation state-of-the-art network safely.
3) Fully develop spatially explicit data collection from radar, airborne remote sensing including atmospheric river reconnaissance (AR-RECON) and ASO snowpack data collection, and satellite remote sensing products. Obtain gridded data sets for precipitation and temperature derived from station-based data collection.
4) Augment observed data sets with Basin Characterization Model (BCM) results to inform the state of the watershed for situational awareness and forecasting work.

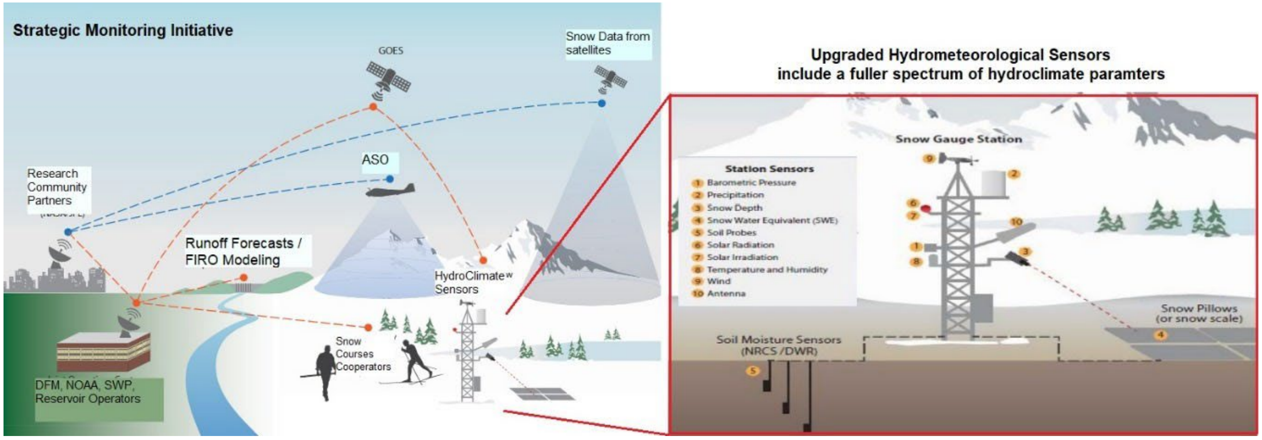

Figure 1. Schematic of improved observing systems supporting climate resilient forecasting framework.

Forecasting Objectives:

1. Adopt new methods currently in development that produce accurate and reliable runoff forecasts for a wider range of weather and climate conditions.
2. Develop a physically based and climate informed modeling framework, noted in figure 2 as the modeling framework, for water supply forecasting based on the iSnoBal and WRF-Hydro platform.
3. Develop as part of the modeling framework shown in Figure 2, a physically based modeling of the Sacramento Basin using WEHY (Watershed Environmental Hydrology) model to integrate snowmelt runoff with baseflow and rainfall- generated watershed runoff.
4. Over the next decade, develop sub-seasonal and long-range weather and climate forecasts.
5. Augment capabilities to use USACE and NWS-CNRFC models for river forecasting and emergency response actions.

Decision Support Objectives:

1. Develop multi-platform (station, airborne, and satellite) observations display for data QA/QC, situational awareness during floods and droughts, and nowcasting capabilities serving flood emergency response and water supply availability.
2. Develop forecast model input file development tool using multi-platform observations to further the use of new and expanded observations being developed.
3. Develop forecast display systems supporting flood emergency response, forecast informed reservoir operations, watershed forecasting, and climate change tracking.
4. Advance data management and resources to effectively maintain a reliable data stream for more robust and data intensive physically based model needs.
5. Develop forecast model performance and hindcast tools available for public consumption to provide transparency in forecast accuracy as well as how climate variability and extremes impact forecast models.

Timeline of Activities

While the initial models and augmented data are anticipated to come online by the start of water year 2025, continued refinement and improvement over the next decade as resources are made available is to be expected. This includes validating newly developed models to measure how well they perform and then to evaluate what further improvements are needed. An expected timeline of implementation is shown in Figure 2.

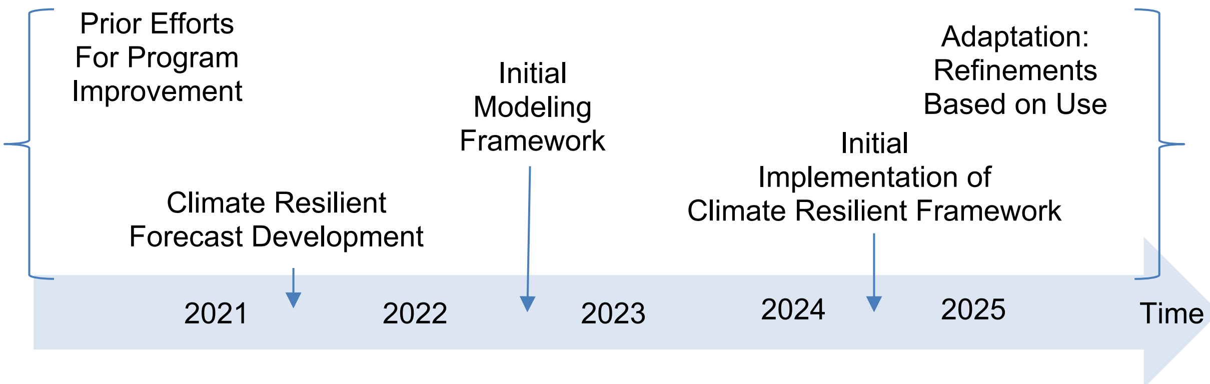

Figure 2. Timeline for developing a climate resilient forecasting framework.

From Roadmap to Implementation

This Roadmap presents fourteen objectives to meet two goals for a climate resilient forecasting framework. The actions, staff resources, and collaborations needed to meet these goals and objectives will be further detailed and updated as needed by the Division of Flood Management in coordination with the State Climatologist. This new framework will generate significantly more data than DWR has previously managed in its forecasting efforts. An information technology computational needs assessment and data management plan will need to be developed.

To ensure this Roadmap remains relevant, a subject matter expert will coordinate ongoing research, development, and implementation associated with the climate resilient forecasting framework. This position will lead roadmap updates as new technology becomes available and new facets of climate change are experienced that impact forecast capability and quality. They will also organize the coordination among different DWR programs that interface with the observations, forecasts, and decision support systems making up the climate resilient forecasting framework.

A central element to this Roadmap will be creating a functional reporting cadence and a web location for interested parties to follow progress. The reporting element will include an annual progress report that records challenges, opportunities, risks and achievements. Finally, work will continue to further develop the California Cooperative Snow Survey's website to provide key information on the forecast process and associated data. New tools and visualizations will be added as they are developed. Together, these reporting elements should provide a clear picture of the DWR's efforts to incorporate new technologies and continue to adapt its observations and forecasting tools to a changing climate.