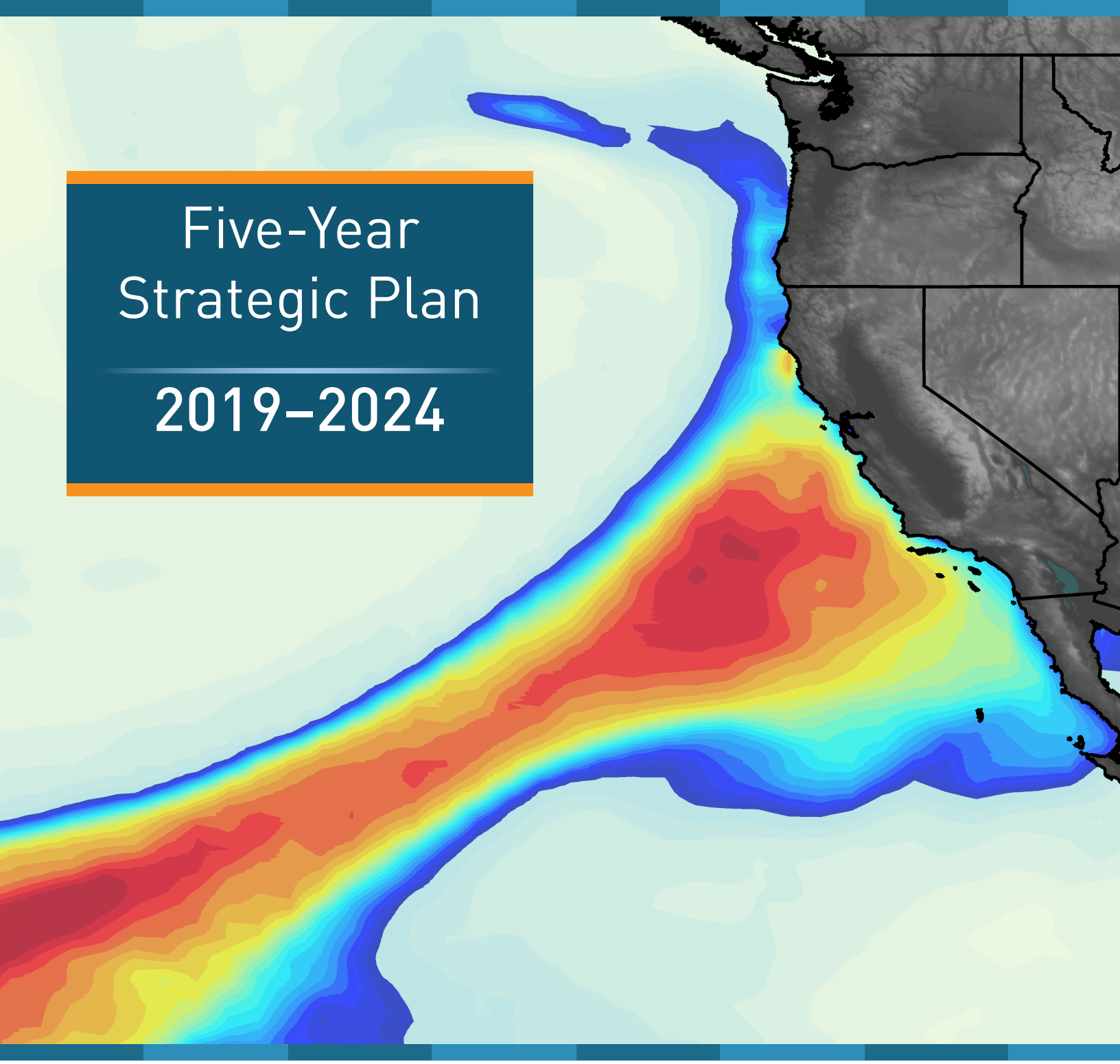


Five-Year Strategic Plan

2019–2024

Center for Western Weather and Water Extremes

UC San Diego | SCRIPPS INSTITUTION OF OCEANOGRAPHY

MESSAGE FROM THE DIRECTOR

Greetings:

It is with great pride that I share the first five years of CW3E's accomplishments and introduce you to our strategic plan for the next five years. This plan represents a new chapter in the Center's development.

I arrived at Scripps Institution of Oceanography in 2013 with high hopes and anticipation of what the Center could become. I knew there was a critical void in addressing the unique needs for science-based information on extreme weather and water events in the western United States. Scripps provided the freedom and support needed to build capacity in this area. The overwhelming response from funders and collaborators has allowed the Center's first five years to surpass my wildest expectations.

The emerging study of atmospheric rivers (ARs) represents a promising direction to build upon, with the goal of connecting science and engineering to solving practical water management and flood control problems for which current meteorological tools are not well suited. Over the last five years, CW3E has played key roles in putting ARs "on the map." ARs are now part of the weather vernacular, our research resulted in the AR scale and AR book, and our AR tools are being applied to improve reservoir operations.

These accomplishments would not have been possible without many talented graduate students, postdocs, staff, and partners, as well as the culture we have created that fosters collaboration and bridges science as a creative enterprise with direction driven by solving practical problems. Our success also reflects the incredible support we have received: from the Scripps Director's Office, which took a chance on this endeavor and continues to support it; from the Scripps business offices that have facilitated our growth; and of course from our sponsors. In particular, I thank the California Department of Water Resources, Sonoma Water, and the U.S. Army Corps of Engineers (USACE) Engineer Research and Development Center for their early and continuing support.

Over the next five years, CW3E will create an even greater impact on science, organizations, policies, and society, as we develop more core capability to support decision-makers who must deal with weather and water extremes. My dream is for CW3E to serve as a hub that fosters the growth of a community of scientists, engineers, policy-makers, and others who

come together to solve major challenges in the West, and broaden our scope nationally and globally, as many of our stakeholders have encouraged us to do.

In advancing our work, we will strive to create new opportunities for people at all career stages and foster a culture of inclusiveness and mutual respect. I hope that people who join our Center, including those who move on to positions elsewhere, develop an awareness that we each can make a difference. Through their energy; scientific, engineering, and administrative contributions; clarity of vision; courage of commitment to their goals; and ability to communicate with others, they can find their passion and voice in the world and help us all deal with the many challenges ahead.

To our colleagues, sponsors, friends and family, and on behalf of our staff and students, please accept my heartfelt gratitude for your contributions and your encouragement in this endeavor.

Marty Ralph

INTRODUCTION

In 2014, the Center for Western Weather and Water Extremes (CW3E) was launched at Scripps Institution of Oceanography at the University of California San Diego to better understand, predict, and apply extreme weather forecasting capabilities tailored to the unique meteorological conditions of the western United States. In just five years, CW3E has become a global leader in cutting-edge research on the science of extreme weather caused by atmospheric rivers (ARs) and is demonstrating applications of this research to improve water resources management in a region where drought and flood cycles are becoming increasingly common and severe.

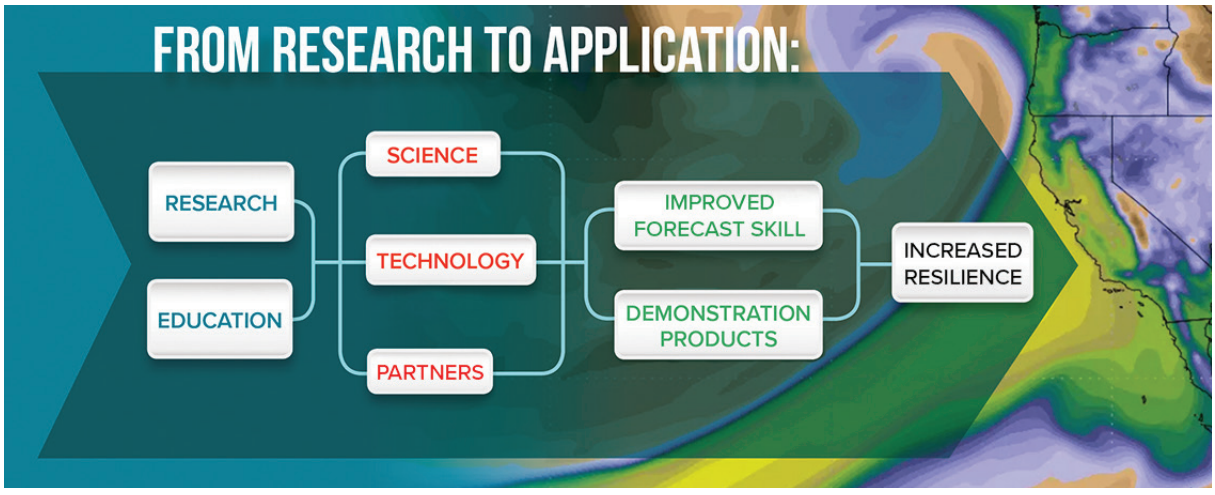
CW3E includes a diverse interdisciplinary team of more than 40 staff, graduate students, and postdocs. This team works with an "extended family" of 13 CW3E-funded collaborators to accelerate the pace of AR discovery and to apply AR science to inform water resources decision-making. CW3E's accomplishments to date include:

- Showing the viability of Forecast Informed Reservoir Operations (FIRO) at Lake Mendocino in the Russian River Basin and expanding FIRO to Prado Dam and the Yuba-Feather watersheds.
- Launching an airborne AR reconnaissance program in cooperation with the California Department of Water Resources, U.S. Air Force, and NOAA.
- Developing the West-WRF model to improve the forecast and analysis accuracy of extreme precipitation events.
- Publishing nearly 100 articles and a book on ARs.
- Implementing an observations network to better understand the relationship between soil moisture measurements and hydrologic model performance.
- Developing a definition of ARs and a scale for measuring AR intensity, both of which are being incorporated into the weather enterprise lexicon.

ARs have a larger impact than any other type of storm in California and along the U.S. West Coast. They deliver 25–50 percent of the water supply in key areas of the West, with tens of billions of dollars in annual benefits. They also play a key role in extreme precipitation and drought. ARs contribute to more than 90 percent of major flood events in the region, at an average cost of $1 billion per year.

This strategic plan aims to build on CW3E's record of success and help the Center:

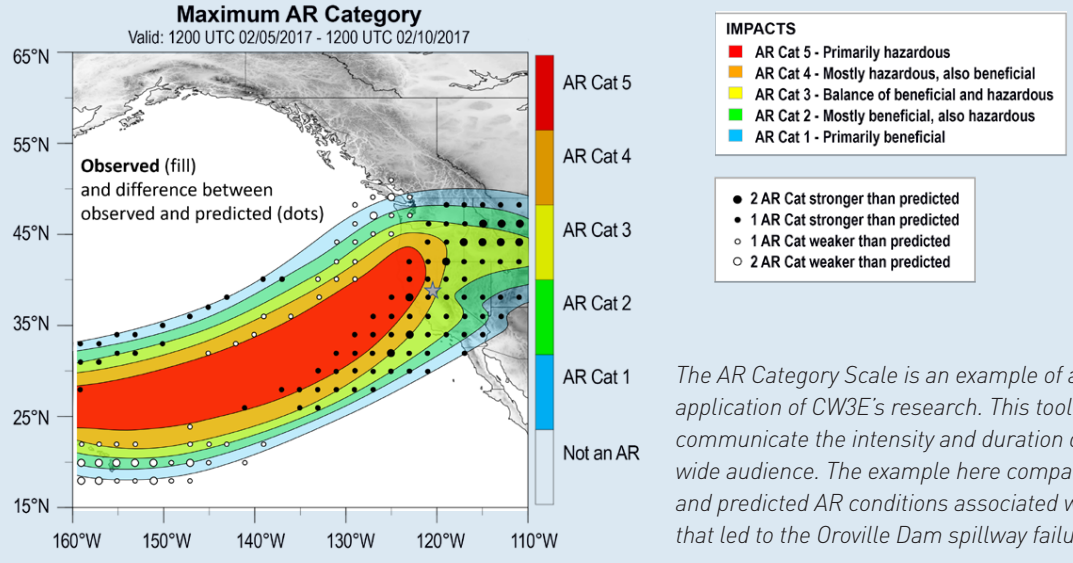
- Set priorities and clear goals for the next five years.
- Focus energy and resources on the highest priorities.
- Work with its partners toward common goals.
- Strengthen and optimize its organization, management, partnerships, communication, resources, and integration into the Scripps educational community.
- Track progress toward shared goals.
- Respond to a changing environment.



CW3E VISION, MISSION, AND GOAL

In its first year of operation, CW3E established a vision, mission, and goal. These fundamental underpinnings of the organization will remain relevant for the next five years.

- **VISION:** Both the natural and socioeconomic system that we depend upon are resilient to extreme weather events and their effects on water supply and flooding.
- **MISSION:** Provide 21st century water cycle science, education, technology, and outreach to support effective policies and practices that address the impacts of extreme weather and water events on the environment, people, and economy of western North America.
- **GOAL:** Revolutionize the physical understanding, observations, weather predictions, seasonal outlooks, and climate projections of extreme events in western North America, including atmospheric rivers, the North American monsoon, and their impacts on floods, droughts, hydropower, ecosystems, and the economy.



The AR Category Scale is an example of a practical application of CW3E's research. This tool helps to communicate the intensity and duration of ARs to a wide audience. The example here compares observed and predicted AR conditions associated with the storm that led to the Oroville Dam spillway failure in 2017.

CORE VALUES

CW3E's core values are central to its success. The Center keeps them at the forefront of strategic planning and reinforces them in day-to-day operations.

- **STUDENT AND STAFF GROWTH:** Create a work environment that promotes the goals of CW3E while enabling professional development, fulfillment, and well-being of team members.
- **DISCOVERY AND PRACTICAL APPLICATIONS:** Create a pathway for worldwide application of CW3E atmospheric modeling advances and deliver research applications through enhanced products and services in partnership with stakeholders.
- **COLLABORATION:** Share knowledge and ideas with universities, river and weather forecasting centers, federal and state agencies, water managers, and emergency managers to support improved prediction capabilities and resilience.
- **EDUCATION:** Integrate CW3E's areas of expertise into graduate-level courses within Scripps to help equip the next generation of researchers and water management professionals with foundational knowledge about Western weather and water extremes.
- **DIVERSITY:** Achieve success by adopting a culture of respect and embracing diversity of gender, academic discipline, race, culture, socioeconomic background, career stage, and other dimensions of diversity to broaden our perspectives and learn from each other.
- **INCREMENTAL AND TRANSFORMATIONAL CHANGE:** Intentionally engage, support, and pursue both incremental (small continuous advancements) and transformational (breakthrough) approaches to research and application.

"Sonoma Water has established a vital partnership with CW3E based on a shared commitment to innovation and the principle that science should inform the decision-making process. Our relationship…has grown to include our funding graduate students to work jointly on some of our most important applied research projects as well as Sonoma Water staff working under contract for CW3E. Our relationship is truly unique and [has] become one of the better examples of an applied public and academic partnership."

— Grant Davis, Sonoma Water

CW3E graduate student Will Chapman releases a radiosonde from the Ukiah Water Treatment Plant during an AR event.

FIVE-YEAR PRIORITIES

Over the next five years, CW3E will focus on six priority areas:

- Forecast Informed Reservoir Operations
- Subseasonal to Seasonal Prediction of Extreme Weather
- Atmospheric Rivers Research and Applications
- Modeling Capabilities for the Western United States
- Monitoring and Projections of Climate Variability and Change
- Emerging Technologies

The pages that follow identify goals and objectives in each of these priority areas, then describe strategic steps that CW3E will take to achieve them.

FIVE-YEAR PRIORITIES

FORECAST INFORMED RESERVOIR OPERATIONS

GOAL: Enable more effective reservoir management through improved weather and water forecasts.

By developing, demonstrating, and implementing objective tools and science, CW3E can create a link between research, applications, and codified operational procedures to enable multipurpose reservoir operators to use the best available science to inform their actions.

> "Over the course of our partnership, CW3E has consistently demonstrated innovation, leadership and scientific rigor in all phases... It is no exaggeration to say that senior policy makers in the USACE are looking to the FIRO effort to set the standard for a new era in water management within the Corps."
>
> —Cary Talbot, U.S. Army Corps of Engineers

Key objectives:

1. Update Water Control Manuals for Lake Mendocino, Prado Dam, Lake Oroville, and New Bullards Bar Reservoir.
2. Create a well-defined pathway for broader application by designing tools and resources that ensure transferability to other reservoirs.

SUBSEASONAL TO SEASONAL PREDICTION OF EXTREME WEATHER

GOAL: Improve atmospheric river prediction on a subseasonal to seasonal (S2S) scale.

CW3E will improve understanding of the S2S predictability of ARs and become a regional leader in producing experimental S2S outlooks of ARs over the western United States.

Key objectives:

1. Apply artificial intelligence and post-processing techniques to improve S2S AR and precipitation prediction skill.
2. Increase understanding and improve skill in forecasting synoptic weather precursor patterns over the western United States that modulate S2S AR and precipitation occurrence and magnitude.
3. Develop and maintain experimental S2S AR outlooks in close coordination with stakeholders.

ATMOSPHERIC RIVERS RESEARCH AND APPLICATIONS

GOAL: Establish global leadership in AR science.

CW3E will increase AR forecasting accuracy by enhancing monitoring and by integrating observations, theory, and modeling into decision support.

Key objectives:

1. Produce scientific publications that further understanding of AR dynamics.
2. Enhance global AR monitoring through a transformative modernization of atmospheric measurements over the Pacific and in the western United States.
3. Produce forecasting and decision support tools that meet the needs of western U.S. forecasters, resource managers, and emergency managers.

A C-130 "Hurricane Hunter" on an AR Recon mission.

MODELING CAPABILITIES FOR THE WESTERN UNITED STATES

GOAL: Improve weather, hydrology, and coupled modeling capabilities for the western United States.

CW3E will develop and contribute to state-of-the-art weather, hydrology, and coupled modeling systems at spatiotemporal scales relevant to water resource and emergency management decisions.

Key objectives:

1. Further develop West-WRF as a cutting-edge numerical weather prediction system with a focus on extreme precipitation events.
2. Develop in-house hydrological modeling capabilities to better support the mission of CW3E's main sponsors.
3. Develop and test coupled weather, ocean, and hydrologic modeling systems to improve prediction of precipitation and streamflow.

> "Localized AR forecasting utilizing CW3E weather models (West-WRF) will improve forecast accuracy, timing, and intensity of AR storms. This improvement, combined with our future secondary spillway, will allow Yuba Water to further optimize water releases ahead of and during storm events, thus reducing downstream flood risk, a primary mission of the Agency."
>
> — Curt Aikens, Yuba Water Agency

MONITORING AND PROJECTIONS OF CLIMATE VARIABILITY AND CHANGE

GOAL: Advance understanding and projections of extreme precipitation events.

CW3E will develop a comprehensive understanding of the physics and the probabilistic and statistical characteristics of extreme precipitation events in the West to inform current and future resource and risk management.

Key objectives:

1. Provide new insights from strategic weather and climate observations and from relevant research on historical and projected extreme events.
2. Enhance decision-makers' conceptual understanding and instrumental knowledge of historical, current, and future extreme events.
3. Develop and apply new approaches for monitoring, characterizing, and predicting the changing physical processes, statistical characteristics, and associated risk profiles of extreme events.

EMERGING TECHNOLOGIES

GOAL: Build skills in data assimilation, artificial intelligence (AI), machine learning (ML), and post-processing algorithms to improve weather prediction.

CW3E will develop and test data assimilation for individual and coupled systems, with a focus on extreme precipitation associated with West Coast ARs. We will build expertise in AI, ML, and post-processing algorithms to add value to weather prediction.

Key objectives:

1. Establish CW3E as a leading center for data assimilation tailored to predicting precipitation, ARs, and extreme events in the West.
2. Develop revolutionary and transformative AI, ML, and post-processing methods to improve the performance of dynamic models.

Current and future collaborations with the San Diego Supercomputer Center will enable new research avenues. Comet, the supercomputer pictured, is at the center of this collaboration. Photo credit: Jon Chi Lou, SDSC/UC San Diego.

ACKNOWLEDGMENTS

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PARTNERS AND COLLABORATORS

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