Study analyzes nearshore California marine heatwaves and cold spells amid changing climate conditions

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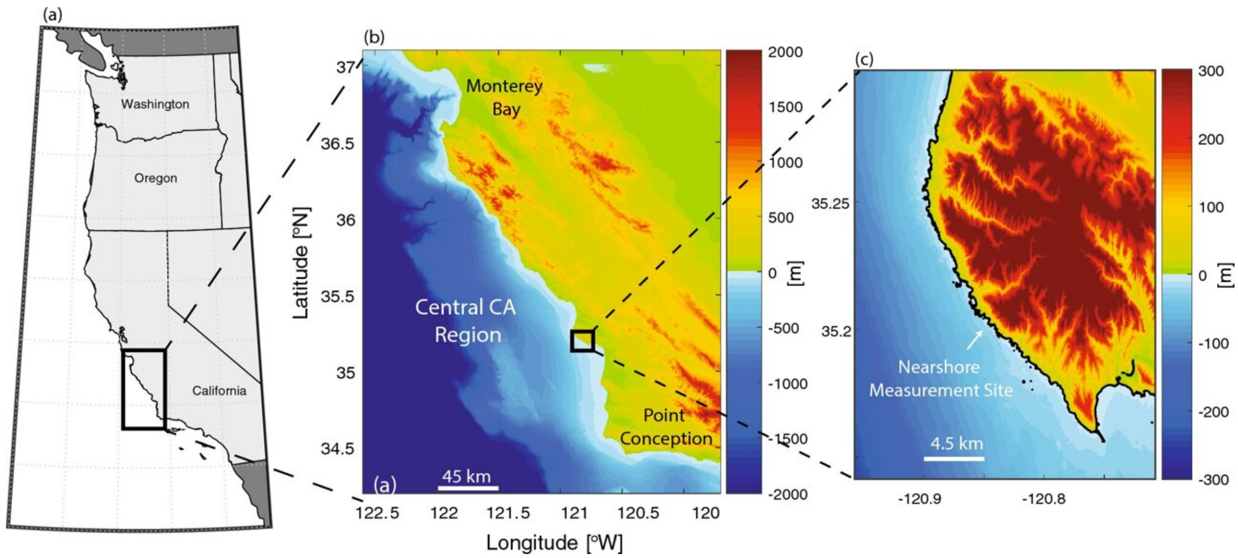

(**a**) US West Coast with Central California region (black box), (**b**) bathymetry and topography of Central California region with nearshore study site location (black box), and (**c**) nearshore measurement site. Maps were generated using MATLAB Version R2022a. Credit: *Scientific Reports* (2023). DOI: 10.1038/s41598-023-39193-4

The first-ever study to look at drivers of both marine heatwaves and cold spells in the shallow nearshore along the California Current—coordinated by California Polytechnic State University, San

Luis Obispo (Cal Poly) and the Virginia Institute of Marine Science, William & Mary—found that certain environmental conditions and the state of the ocean can lead to an enhanced risk for ocean temperature extremes.

The findings were recently published in *Scientific Reports* in an article titled "Effects of basin-scale climate modes and upwelling on nearshore marine heatwaves and cold spells in the California Current."

Extreme marine heatwaves, which can cause detrimental effects to marine ecosystems and ocean-related ecology, are exacerbated by rising global temperatures like those of 2023, which is shaping up to be one of the hottest years on record worldwide. Using temperature data that spanned four decades, the researchers identified environmental conditions that led to extreme warm and cold periods.

Scientists and environmental managers can use these findings to inform the preservation and protection of vital ecosystems critical to the California ocean economy, known as the Blue Economy.

When ocean temperatures along the California coast warm during El Niño years, such as the one forecasted to take place this winter, marine ecosystems can be severely impacted if temperatures get too hot. In the past, these marine heatwaves have led to giant kelp forest loss, mass die-offs of seabirds and economically important fisheries, and harmful algal blooms.

There is high confidence in the scientific community that, because of climate change, El Niño events will increase in frequency and intensity with potential for harmful effects on marine ecosystems and ocean-related ecology, said Ryan Walter, a Cal Poly physical oceanography associate professor and article co-author.

"And so, if we have stronger El Niño events in the future, we expect to see more frequent and more extreme marine heatwaves and all the consequences that come with it," Walter said. During the last major El Niño in 2015-2016, a long duration marine heat wave contributed to the collapse of the iconic and species-rich kelp forests in parts of California.

Along with variable ocean and weather conditions caused by events such as El Niño and La Niña years, the study found that upwelling patterns on a short-term basis also can initiate some of these marine heatwaves and cold spells, depending on if the upwelling and related cooling effects are stronger or weaker.

It has long been known that coastal upwelling—the wind-driven transport of deep, cold water into shallow areas along the coast—has a strong cooling effect on coastal waters, creating foggy marine layers and stimulating marine productivity. Upwelling helps to maintain healthy fisheries and robust marine life. The cold waters also help buffer against rising water temperatures frequently found farther from shore.

"If we didn't have upwelling along our coast, we'd see far more heatwaves," Walter said. "So, the upwelling is cooling down nearshore regions along the coast and causes the climate change-induced warming signal to be more muted. This also provides a thermal refuge for marine organisms."

Thermal stress, both hot and cold, can significantly affect aquaculture and fisheries, both important components of California's Blue Economy. In the future, it will be important to understand how changes in wind patterns and surface warming from climate change will affect upwelling along California's coast.

"Upwelling systems in general are among the world's most productive ecosystems, including many of the world's fisheries and beautiful kelp forests," Walter said. "Because the deep upwelled waters are cold, they help mitigate some of the warm water extremes. Additionally, these deep, cold waters are full of nutrients and when they upwell, they effectively fertilize the surface of the ocean and lead to strong biological productivity."

Cal Poly undergraduate physics major Michael Dalsin served as the lead author of the journal article along with co-authors Walter and Piero Mazzini, a physical oceanography professor at the Virginia Institute of Marine Science at William & Mary.

The team analyzed ocean temperature data, spanning from 1978-2020, taken in a fixed location in shallow water near the coastline of Diablo Canyon Nuclear Power Plant on California's Central Coast. The unique reference point is insightful because coastal ocean temperature data lasting more than three decades is less common and needed to statistically quantify the extreme events. Also, temperature data close to shore collected from satellites has interference caused by fog and lower in resolution, the researchers said.

"This study lays the foundation for understanding how temperature extremes in our ocean will respond to climate change," said Dalsin, an undergraduate who has won multiple awards for his work on the study, including an American Meteorological Society (AMS) Student Award for his oral presentation at the 2023 annual meeting. He was also one of 10 students selected to represent Cal Poly at the 2023 Cal State Student Research Competition.

"One fascinating aspect of our research is that we can predict the likelihood of one of these extreme marine events given the state of our ocean," Dalsin added. "The state of the ocean, as determined by large-scale climate modes and local-scale upwelling winds, could be used to forecast heatwaves and cold spells in the future."

This research provides a better understanding of the when, where, and why these marine extreme events occur. "One thing, however, is clear," said Walter, "These extreme temperature events are not going away so it is critical that we continue to explore their drivers and consequences."

More information: Michael Dalsin et al, Effects of basin-scale climate modes and upwelling on nearshore marine heatwaves and cold spells in the California Current, *Scientific Reports* (2023). DOI: 10.1038/s41598-023-39193-4

Provided by California Polytechnic State University

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