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Climate modelers add ocean biogeochemistry and fisheries to forecasts of future upwelling

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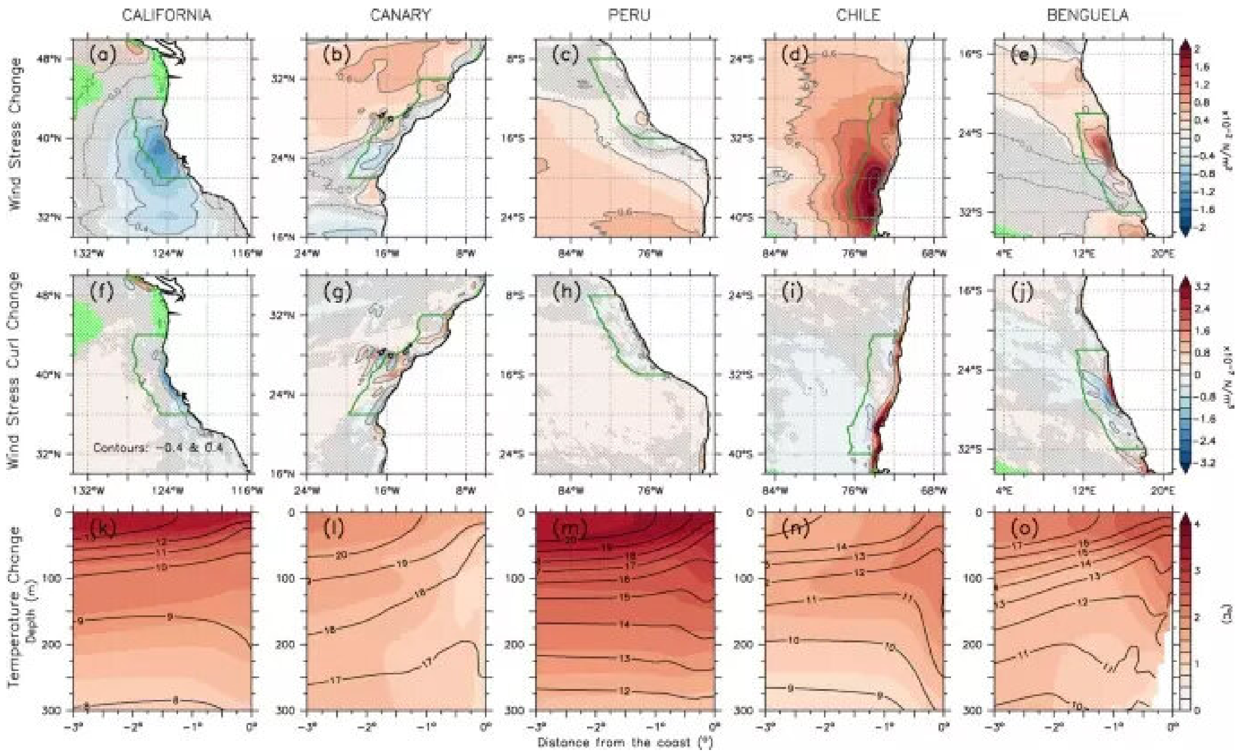

Projected change (defined as the mean over the future period of 2071–2100 minus the mean over the historical period of 1991–2020) of alongshore wind stress (×10−2 N m−2) shown in longitude-latitude plane (upper) for CCS (a), CUS (b), P-CUS (c, d), BUS (e), and projected change of wind stress curl (×10−7 N m−3) (middle) for CCS (f), CUS (g), P-CUS (h, i), BUS(j). Credit: Chang, P., Xu, G., Kurian, J. et al.

A handful of hyper-productive fisheries provide sustenance to a billion people and employ tens of millions. These fisheries occur on the eastern edges of the world's oceans—off the West Coast of the U.S., the Canary Islands, Peru, Chile, and Benguela. There, a process called upwelling brings cold water and nutrients to the surface, which in turn supports large numbers of larger sea creatures that humans depend on for sustenance.

A new project led by researchers at Texas A&M University is seeking to understand how changes to the climate and oceans will impact fisheries in the U.S. and around the world.

"We're interested in how climate change is going to alter upwelling and how the sustainability of the future fisheries will be impacted," said Ping Chang, Louis & Elizabeth Scherck Chair in Oceanography at Texas A&M University (TAMU). "It turns out that when we increase the resolution of our climate models, we find that the upwelling simulation becomes much closer to reality."

Funded by the National Science Foundation (NSF), the project aims to develop medium to long-term fishery forecasts, driven by some of the highest-resolution coupled climate forecasts ever run. It is one of the 16 Convergence Accelerator Phase 1 projects that address the 'Blue Economy'—the sustainable use of ocean resources for economic growth. Convergence projects integrate scholars from different science disciplines.

The TAMU team, led by oceanographer Piers Chapman, includes computational climate modelers, marine biogeochemical modelers, fishery modelers, decision support system experts, and risk communications scholars from academia, federal agencies, and industry.

Chang and Gokhan Danabasoglu at the National Center for Atmospheric

Research (NCAR) lead the climate modeling component of the research. They use the Frontera supercomputer at the Texas Advanced Computing Center (TACC)—the fastest academic supercomputer in the U.S.—to power their research.

In the 1990s, marine biologist Andrew Bakun proposed that a warming climate would increase upwelling in the eastern boundary regions. He reasoned that since land is warming faster than the oceans, the temperature gradient between land and ocean would drive a stronger wind, which makes upwelling stronger. However, recent historical data suggests the opposite might in fact be the norm.

"A lot of papers written in the past use coarse resolution models that don't resolve upwelling very well," Chang said. "High resolution models so far predict upwelling in most areas, not increasing. The models are predicting warmer, not colder temperatures in these waters. In Chile and Peru, the warming is quite significant—2-3ºC warming in the worst case scenario, which is business as usual. That can be bad news for upwelling."

The areas where upwelling occur are quite narrow and localized, but their impact on the marine ecosystem is very large. The eastern Pacific upwelling, for instance, is only about 100 kilometers wide. The climate models used by the Intergovernmental Panel on Climate Change (IPCC) have a resolution of 100 kilometers—and would therefore only produce one data point for the upwelling region, not nearly enough to predict future changes accurately.

On the other hand, the model used by Chang and his colleagues uses a resolution of 10 kilometers in each direction. These are 100 times more resolved than the IPCC models—and require roughly 100 times the compute power.

Chang's study relies on two separate, but related, sets of simulations. The first set involves an ensemble (the same model run with a slightly different starting point to produce a statistically valid result) of high-resolution coupled Earth system models. The second incorporates observed data in the atmosphere to generate realistic ocean states that are then used to initialize the model prediction. Starting from 1982, it will perform five-year retrospective forecasts to determine the skill of the model in forecasting upwelling effects.

"There's a limit to how far out you can make a forecast," Chang said. "Beyond a certain time limit, the model no longer has skill. At five years, our model still shows useful skill."

The team reported their results in Nature's *Communications Earth & Environment* in January 2023.

The Blue Economy project continues the TAMU-NCAR team's multi-decade effort to upgrade global climate models so they are higher resolution and more physically accurate. The model used by the team was one of a handful of high-resolution Earth system models that were included in the most recent IPCC report and are being explored by an IPCC subcommittee. They represent the future of global climate modeling.

At 10 kilometer resolution, researchers believe it is possible for models to realistically generate extreme weather events like tropical cyclones or atmospheric rivers, as well as more refined predictions of how climate in a specific region will change. However, models at this resolution still cannot resolve clouds, which requires models with a few kilometer resolution and can currently only be integrated for short-term, not climate, timescales.

The effort to capture the Earth system continues to improve.

The TAMU-NCAR project will be one of the first to incorporate biogeochemical models of the ocean and fisheries models into Earth system models at 10 km resolution.

"TACC is unique in providing resources for researchers like us to tackle the fundamental questions of science," Chang said. "Our goal is not routine forecasts. What we want is a better understanding of the Earth system dynamics that are missing in current climate models to make our model and our methods better. Without Frontera, I don't know if we could make simulations like we do. It's critical."

More information: Ping Chang et al, Uncertain future of sustainable fisheries environment in eastern boundary upwelling zones under climate change, *Communications Earth & Environment* (2023). DOI: 10.1038/s43247-023-00681-0

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