Microsoft

AI for Earth Grantee Profile

University of Washington

Forecasting marine heatwaves in time and space

Summary

Marine heatwaves cause many adverse impacts, from disruptions in the marine food chain to declines in fish stock and consequent harm to the fishing industry and rise in economic and political tensions. Early detection and prediction of marine heatwaves can inform better decisions to protect marine ecosystems and manage human activities. Using observational records, scientists have been able to study past marine heatwaves and their drivers, as well as predict future statistics based on climate change projections. However, it's been difficult to anticipate when, where, and for how long future marine heatwaves will exist. Hillary Scannell and her advisor, LuAnne Thompson, of the University of Washington School of Oceanography will apply AI tools to learn the spatio-temporal patterns of historical marine heatwaves, then use a large climate model database to anticipate future marine heatwaves.

Understanding and predicting marine heatwave trends

The ocean is Earth's largest reservoir of excess heat, and therefore plays a critical role in regulating temperature, both on a seasonal basis and over longer timescales. Climate change has resulted in prolonged, more frequent periods of thermal stress in the ocean—marine heatwaves—that can cause coral bleaching or death, declines in fish populations, death of marine invertebrates, and disruption to the distribution of species

> There are 64 identified large marine ecosystems worldwide that produce over 80% of the world's fish.
> —*Sustaining the World's Large Marine Ecosystems*, IUCN

that the fishing industry relies on. A 2018 *Nature Communications* article concluded that global average marine heatwave frequency increased by 34 percent from 1925 to 2016, and duration of these heatwaves increased 17 percent. High-profile marine heatwaves over the past decade, like the Blob from 2013 to 2016, have raised awareness of these events and spurred research around detecting, tracking, and predicting them. The Blob affected the Pacific Ocean from Mexico to Alaska and resulted in the deaths of whales, fish, and hundreds of thousands of birds. It's expected that marine heatwave events will become more frequent and more intense due to human-induced climate change, increasing the urgency to develop new approaches to mitigating and responding to marine heatwaves.

Because of the effect marine heatwaves have on important marine ecosystems, Hillary Scannell and LuAnne Thompson of the University of Washington School of Oceanography have decided to focus work on using AI to detect and forecast marine heatwaves headed towards large marine ecosystems, where marine heatwaves are known to have devastating effects. There are 64 identified large marine ecosystems worldwide that produce over 80 percent of the world's fish, making them a logical target for focused sustainability efforts. In fact, "by 2050, marine heatwaves will double the impact to important fishery species like pollock, cod and salmon over previous predictions that only took into account the effects of climate change." Previous research has largely focused on heatwaves in a fixed space over time; predictive research has been hindered by lack of historical records (dating back only to 1981). Scannell and Thompson aim to follow marine heatwaves in both time and space and utilize advanced AI tools combined with multi-century climate model simulations to overcome past limitations.

Applying big data tools to climate science

The Microsoft grant allows the University of Washington to more easily store the vast amounts of data necessary for the project, and provides scalable computing power to create, train, and validate an AI model that shows how marine heatwaves evolve in size, intensity, duration, and location. Because of the short observational record of global sea surface temperature measurements, there is limited data around marine heatwave events to train a deep learning model. One of the core strategies of this project is to use an ensemble of 40 global climate simulations called the Community Earth System Model Large Ensemble. Each simulation evolves under slightly different initial conditions to reproduce the inherent natural variability within the climate system. Thompson explains, "If you look at the Pacific Northwest marine heatwave, which is called the Blob, we've now seen a really big one in 2014 and then again 2018 to 2019, and then one smaller one in 2005, so we only have three samples in this region. But, if we have 40 model simulations, we can multiply that [dataset] by 40. So now instead of only three samples, we have 120 samples of these marine heatwaves. Then you have more samples going into the future, so that builds this statistical robustness in terms of what we've learned about how these marine heatwaves move in space, how often they'll happen, how big they might be, and what factors might influence how big and where they are."

Providing advance notice around heatwave events

Anticipating the paths of destructive marine heatwaves provides warning for fisheries and aquaculture farmers, and will help guide scientists in deploying autonomous instruments (for example, ocean gliders, pH sensors, sail drones, and profiling floats), as well as in designing biological surveying to better monitor and predict the impacts from these deadly events. Scannell says, "I get the sense that [fisheries] need about five days to a week to make changes, whether that's taking out a raft of mussels and moving it to a different area where they can mitigate the extremes in temperature, or changing their fishing season, or going out later to give population a break. Even knowing that there's a chance that this marine heatwave could last for a month is better than not having that predictability."

> "Even knowing that there's a chance that this marine heatwave could last for a month is better than not having that predictability."—Hillary Scannell

Results from this project will be shared to communities affected by marine heatwaves, policymakers, and natural resource managers to inform responses to a changing climate system. Scannell and Thompson will partner with key stakeholders, including Jan Newton from the Northwest Association of Networked Ocean Observing Systems (NANOOS), to disseminate AI tools more broadly. This will allow vulnerable fisheries to be safeguarded and to manage the impacts from destructive marine heatwaves, particularly in the California Current Large Marine Ecosystem. The sharing of information may consist of a series of webinars to explain the developed AI tools, as well as a bulletin with up-to-date information on real-time marine heatwave conditions and forecasts.

About Hillary Scannell

Hillary Scannell is a PhD candidate in the Ocean Climate Variability Lab at the University of Washington, using machine learning to predict the geospatial distribution of marine heatwaves under natural and forced climate change. She holds a BS in Marine Science and an MS in Oceanography from the University of Maine. Being eyewitness to an unusual warming event in the Gulf of Maine during the summer of 2012, coupled with a curiosity for ocean physics, solidified Scannell's decision to pursue graduate work related to oceanographic temperature extremes. Her research spans the domains of ocean, climate, and computer sciences, and makes use of large and complex datasets from ocean buoys to satellites and global climate models. Scannell received an AI for Earth Azure Compute Grant to port some output to Azure and to begin preliminary analysis of the statistics of marine heatwaves in this dataset on a large virtual machine.

About LuAnne Thompson

Oceanographer LuAnne Thompson, the Walters Endowed Professor, uses climate models along with satellite observations to understand the role that the ocean plays in moving and storing heat and chemicals in the climate system. She is the former Director of the Program on Climate Change at the University of Washington. Through this, Thompson got to know faculty and students who care deeply about the future of the planet and who are doing groundbreaking work to understand our climate system, the changes that we are seeing now, and what we expect will occur in the future. She has also been involved in interdisciplinary collaborations that address the challenges that climate change will bring to natural and human systems.

Resources

Websites

http://faculty.washington.edu/luanne/

https://www.hillaryscannell.com/

Documentation

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