Tracking the spatiotemporal evolution of marine heatwaves globally

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Background & Motivation

- Dangerous hot-water events, called **marine heatwaves** (MHWs), cause prolonged periods of thermal stress in the marine environment that can lead to widespread coral bleaching, harmful algal blooms, unproductive fisheries, and even economic loss.
- Anticipating the paths of destructive MHWs remains a challenge owing to the complex spatiotemporal evolution of these events and the lack of tools available to identify and track MHWs as they move throughout the ocean.
- To overcome these challenges, we have developed an open source Python package called **Ocetrac** to label and track unique geospatial anomalies.
- Using **Ocetrac**, we characterize new spatial patterns and behaviors of some of the most dangerous MHWs of the 21st Century.

Methods & Software Development

- Ocetrac achieves three primary goals: **(1) feature extraction** of extreme data points, **(2) object detection** to identify contiguous features, and **(3) multiple object tracking** to label and track similar MHW events in both time and space.
- We analyze monthly satellite-derived NOAA Optimum Interpolation Sea Surface Temperature from September 1981 through January 2021.
- During feature extraction, the local 40-year mean, trend, annual and semiannual harmonics of SST are removed using least-squares regression to compute anomalies. We then identify candidate MHW grid points when SST anomalies exceed the local 90th percentile.
- Morphological operations of dilation and erosion are then performed to detect spatially distinct objects from these maps. Only MHW objects whose area exceeds a specific size threshold are tracked.

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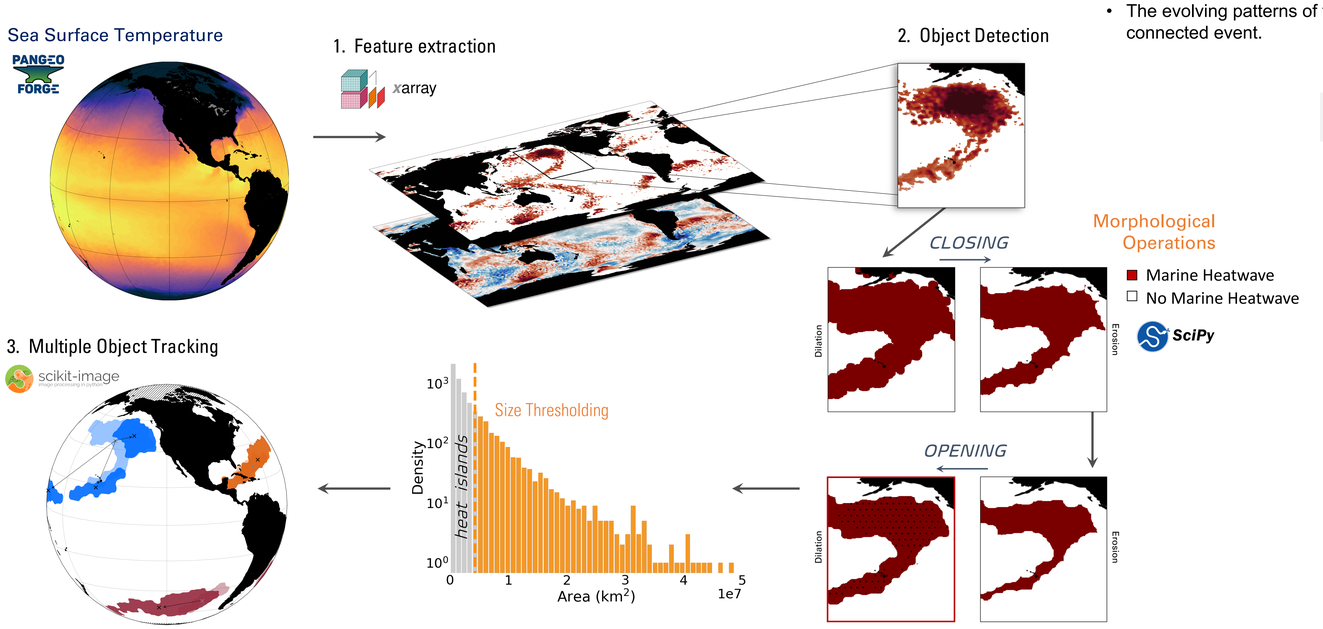
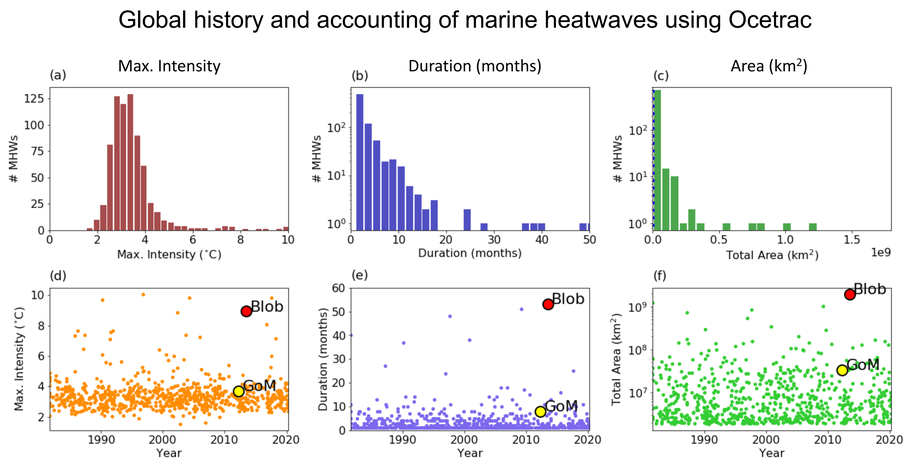
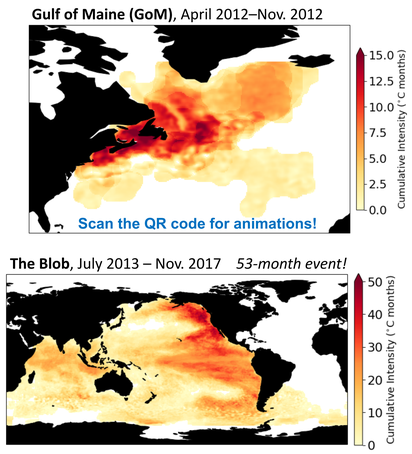
https://ocetrac.readthedocs.io



Results

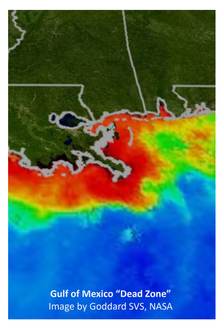




- Ocetrac provides a new global dataset of MHW metrics that we can then probe to characterize past event and describe their evolutions. Here we focus on two well-known MHWs: the 2012 event in the Gulf of Maine and 2013–2017 "Blob" event in the Pacific.
- The Gulf of Maine MHW was a localized event that peaked during the summer of 2012. It's maximum intensity, duration and area were much less compared to the multi-year persistence of the Pacific MHW known as the Blob.
- Multiple documented MHWs from 2013–2017 are in fact a single super-connected event that lasted over 4 years. This global event had a significant ocean footprint reaching from the tropics to the mid-latitudes and encompassing the Northeast Pacific MHW known as "the Blob" in 2014–2016, the Tasman Sea MHW in 2015/16, the Santa Barbara event in summer 2015, and the Great Barrier Reef MHW in 2016. Only the North Atlantic was spared.
- The evolving patterns of tropical Pacific sea surface temperature and associated atmospheric teleconnections are likely a significant driver of this globally connected event.

Summary & Future Direction

- Two different types of MHW patterns emerge: localized events that grow in place and globally connected events that are linked through the tropics.
- MHWs with global connectivity tend to be longer lasting and more intense compared to localized events.
- The tropics provide an important conduit for extremely large-scale and persistent marine heatwaves.
- We present **Ocetrac**, a community driven package for the detection of extreme events in gridded datasets. Future work could look at how well Ocetrac characterizes other extreme hazards such as coastal flooding, hypoxia (example image to the right), oil spills, and low pH events.
- By providing a flexible, interoperable, and open-source package to carry out these specialized calculations, we hope to empower other researchers to adopt, reuse, and remix our feature-tracking methodology as part of their own workflows.



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