**Southern California Health & Air Quality**

*Using Remote Sensing to Detect the Frequency and Drivers of Red Tide Blooms in California to Assist in the Management of Human and Marine Exposure to Algal Toxins*

**Project Team**

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**Project Overview**

***Project Synopsis:***

The Southern California Health & Air Quality project aimed to increase the capabilities of detecting red algal blooms of *Lingulodinium polyedra* in the Southern California Coastal Zone from 2010 to 2021. In collaboration with several California-based coastal management agencies, the team utilized NASA and JAXA Earth observations, validated by *in-situ* water quality data, to develop an interactive tool visualizing various chlorophyll measurements and detecting harmful algal blooms (HABs) over time. The end products allowed end-users to visualize historical dinoflagellateblooms and increased their understanding of how human and marine exposure to algal toxins can be better addressed.

***Abstract:***

In 2020, the dinoflagellate species *Lingulodinium polyedra* was measured at unprecedented levels off the southern California coast, raising concern for local communities. At high levels, *L. polyedra* can cause marine life mortality, food-borne illness, and respiratory-related health risks in humans. In partnership with the California Office of Environmental Health Hazard Assessment, the National Oceanic and Atmospheric Administration Southwest Fisheries Science Center, the California Department of Public Health, and the University of California San Diego’s Scripps Institution of Oceanography, this project utilized satellite imagery to visualize and analyze spatiotemporal trends of historical red tide events associated with *L. polyedra*. Using the Suomi National Polar-orbiting Partnership’s (NPP) Visible Infrared Imaging Radiometer Suite (VIIRS), Aqua’s Moderate Resolution Imaging Spectroradiometer (MODIS), and Global Change Observation Mission – Climate (GCOM-C) Second Generation Global Imager (SGLI), the team assessed the validity of using multiple sensors in detecting chlorophyll-a as a proxy for dinoflagellate dominated-algal blooms. The results suggest that VIIRS imagery processed using the Color Index algorithm from Hu et al. (2013), amongst all other algorithms and Earth observations assessed, shows the most promise in identifying *L. polyedra* blooms. The end products included an ArcGIS Dashboard and Google Earth Engine tool that when combined, provided users with spatial and temporal trends, interactive interfaces to analyze the effectiveness of various sensors and algorithms, and an overall contribution to aid in the management of human health and the economy impacted by harmful algal blooms.

***Key Terms:***

algae, Harmful Algal Bloom (HAB), remote sensing, chlorophyll-a, phytoplankton, *Lingulodinium polyedra*, Southern California Bight

***National Application Area Addressed:*** Health & Air Quality

***Study Location:*** Southern California Coastal Zone, CA

***Study Period:*** January 2010 to November 2021

***Community Concerns:***

* In recent years, red tide events have become more frequent and widespread throughout the Southern California coast. In 2020, the University of California-San Diego Scripps Institution of Oceanography (SIO) observed the highest ever concentration of *L. polyedra*, a particularly toxic dinoflagellate that can cause these HABs.
* *L. polyedra* contains yessotoxin, a biotoxin that poses adverse human health effects if accumulated in abundance. Such effects include chest and abdominal muscle paralysis, which can lead to breathing issues among southern California beachgoers who are exposed to these HABs.
* Further concerns regarding red tide events are the deleterious implications they have on marine ecosystems and fisheries. These events can lead to increased fish and marine mammal mortality, shellfish poisoning, and even food-borne illness when harvested.
* Mass mortality events of marine animals can also have economic impacts caused by the closure of fish and shellfish fisheries, as well as a decrease in coastal recreation, tourism, and sport fishing, which may be the primary industry for surrounding communities.

***Project Objectives:***

* Generate an interactive tool using Google Earth Engine and ESRI’s ArcGIS Dashboard, that visualizes water quality parameters and HAB extents in southern California over time
* Detect and monitor recent red tide bloom extents and movement using NASA and Japanese Aerospace Exploration Agency (JAXA) Earth observations
* Cross-validate remotely sensed bloom parameter data with both *in-situ* data and JAXA Earth observations to assess validity of using remotely sensed NASA Earth observation data products for future HAB detection

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **California Office of Environmental Health Hazard Assessment** | Beckye Stanton, Staff Toxicologist; Shannon Murphy, Staff Toxicologist | End User | No |
| **National Oceanic and Atmospheric Administration, Southwest Fisheries Science Center** | Toby Garfield, Environmental Research Division Director | End User | No |
| **California Department of Public Health** | Vanessa Zubkousky, Senior Environmental Scientist | End User | No |
| **University of California San Diego, Scripps Institution of Oceanography** | Clarissa Anderson, Biological Oceanographer;  Andrew Barton, Assistant Professor; Jeff Bowman, Assistant Professor;  Mati Kahru, Research Oceanographer; Melissa Carter, Research Staff;  Megan Hepner-Medina, Support Staff | Collaborator | No |

***Decision-Making Practices & Policies:***

The National Oceanic and Atmospheric Administration (NOAA) Southwest Fisheries Science Center (SWFSC) conducts scientific research to support healthy and sustainable marine ecosystems, along with fisheries management in California. Currently, most of their research consists of aquatic field surveys to monitor environmental threats to California’s fisheries. The California Office of Environmental Health Hazard Assessment (OEHHA) focuses on quantifying the potential health risks caused by environmental hazards such as marine toxins from HABs. They work with the California Department of Public Health (CDPH) to advise local water body managers regarding harmful bloom spread. Currently, their hazard assessments rely mostly on reported sightings, specifically reported illnesses considered to be related to HABs. Each of these end users support local management of communities and systems affected by HABs, primarily using data collection processes that could be enhanced and further expanded by incorporating NASA Earth observations into their tracking methods.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **GCOM-C SGLI** | Chlorophyll-a, Sea Surface Temperature, Remote Sensing Reflectance at 380/443nm band ratio as *L. Polyedra* bloom indicator | These data were used to analyze changes in water quality parameters by utilizing wavelength specific reflectance and radiance from 2020-2021. |
| **Aqua MODIS** | Chlorophyll-a, Sea Surface Temperature | These data were used to analyze changes in water quality parameters from 2010 and forward to determine season and annual trends for time series analyses and the extent of annual red tide events. |
| **Suomi NPP VIIRS** | Chlorophyll-a, Remote Sensing Reflectance | These data were used to analyze changes in water quality parameters from 2010 and forward to determine seasonal and annual trends for time series analyses and the extent of annual red tide events. |

***Ancillary Datasets:***

* Southern California Coastal Ocean Observing System (SCCOOS) Harmful Algal Bloom Monitoring Alert Program (HABMAP): CalHABMAP - Santa Monica Pier HAB data repository – *In situ* time series data including average chlorophyll-a measurements used for cross validation analysis with satellite imagery data.
* SCCOOS HABMAP: CalHABMAP Scripps Pier HAB data repository – *In situ* time series data including average chlorophyll-a measurements used for cross validation analysis with satellite imagery data.

***Software & Scripting:***

* ArcGIS Pro 2.8.3 – Raster manipulation and map production
* ArcGIS Dashboard – Visualization, interaction, and community outreach platform
* Google Earth Engine Application Programming Interface (API) - Processing of satellite imagery and application of ocean color detection algorithms
* Python 3.8 – Validation, data management, and data plotting

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Southern California Health and Air Quality Dashboard** | Aqua MODIS, Suomi NPP VIIRS, GCOM-C SGLI | This tool will allow partners to visualize water quality and bloom extent data, identify spatial patterns and trends, and locate areas of interest and frequency to better understand the correlation between chlorophyll-a concentration and *L. polyedra* presence. Created in ArcGIS Dashboards. | N/A |
| **Southern California Health and Air Quality Google Earth Engine Tool** | Aqua MODIS, Suomi NPP VIIRS, GCOM-C SGLI | This interactive tool will allow partners and community members to visualize historical algae blooms, the water quality characteristics, and the spatial extent of algal blooms over a 10-year period. | III |

***Product Benefit to End User:***

The end results of this project will provide the partners with an interactive and easy-to-navigate platform that highlights red tide bloom trends along the California coast over the past 10 years, along with the health impacts HABs can have on both marine life and humans. The ArcGIS dashboard will help end users better understand bloom dynamics, including timing, magnitude, and extent, along with the driving forces behind them. The Google Earth Engine tool will place an emphasis on the viability of NASA Earth observations for future bloom detection. End products can be incorporated into water manager’s current bloom monitoring efforts, and later used to better inform their decision-making processes surrounding recreation and fisheries management practices surrounding these HABs. Beyond this, these tools will provide the general public with education and awareness regarding the increased frequency and danger of toxic algae blooms along the southern California coast and will enable them to take action towards management, policy, and eventually mitigation.

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