**Hawaii Island Climate**

*Utilizing Earth Observations to Delineate Wetland Extents, Model Sea Level Rise Inundation Risk, and Assess Impacts on Historic Hawaiian Lands*

**Project Team**

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**Project Overview**

***Project Synopsis:***

Coastal areas of Hawaii Island face significant erosion due to climate change induced sea level rise. The Hawaii Climate Change Mitigation and Adaptation Commission’s 2017 report estimated 4,550 acres of land may be lost if action is not taken. Our NASA DEVELOP team created a short-term sea level rise inundation risk model and a probability-based wetland extent map to evaluate risks to historic cultural lands throughout the island. The quantification of short-term sea level rise risk and delineation of wetlands will aid the County of Hawaii and State of Hawaii in decision-making for their Shoreline Setback and Climate Adaptation Plans.

***Abstract:***

Climate induced sea level rise poses a risk to coastal areas on the Island of Hawaii and many of the island’s historic cultural lands are in danger of becoming inundated. In partnership with the County of Hawaii, the State of Hawaii Department of Land and Natural Resources, and Arizona State University, our NASA DEVELOP team modeled short-term sea level rise inundation risk and wetland extent. Our team utilized NASA Earth observations over a 10-year span (2013 – 2022) that include data from NASA MEaSUREs Gridded Sea Surface Height Anomalies (SSHA) and the Group for High Resolution Sea Surface Temperature (GHRSST) to model sea level rise inundation risk. We used a random forest model to classify short-term inundation risk along the entire coast of Hawaii for five known local flood events from 2019 – 2021, using physically related features like sea surface height anomalies and soil permeability. Additionally, our team compared the *in-situ* local tidal gauge data at two sides of Hawaii Island to the SSHA data. Current wetland extents and probabilistic locations of new wetlands were modeled with data from PlanetScope Surface Reflectance optical imagery (2022), United States Geographic Survey (USGS) 3D Elevation Program 10m DEM (2013), temperature and precipitation data from the Hawaii Climate Atlas (2021), and soils data from the Hawaii Soil Atlas (2014) using the Wetland Intrinsic Potential (WIP) tool. Results indicated locations with the highest probability for wetlands. Our project deliverables will assist our partners in their efforts to meet regulation requirements for wetlands protection, evaluate short-term sea level inundation risk, and guide decision-making for their Shoreline Setback and Climate Adaption plans.

***Key Terms:***

remote sensing, wetlands, sea level rise, random forest, inundation risk, NASA MEaSUREs, Sentinel-1

***National Application Area Addressed:*** Climate

***Study Location:*** Hawaii Island, HI

***Study Period:*** January 2013 – May 2022

***Community Concerns:***

* Shoreline erosion and sea water intrusion from sea level rise has documented consequences such as damage to local structures, homes, roads, and habitats from inundation.
* Local trail infrastructure, archaeological sites, religious sites, burial sites, and homes are affected by both sea level rise and erosion. Many of these heritage sites hold strong cultural value and are presently used but are not currently protected by law. Coastal inhabitants range from subsistence fishing villages to mega-mansions and hotels.
* The total amount of community-owned properties shrinks, such as home properties, are submerged by sea level rise encroachment, particularly in main urban areas like Kona and Hilo bay.
* The tourism industry of Hawaii Island has over 1.5 million visitors, placing great demand on housing, critical infrastructure, and natural resources according to the Hawaii Climate Change Mitigation and Adaptation Commission’s 2017 report.

***Project Objectives:***

* Create an up-to-date coastal wetlands extent map of Hawaii, showing the probability of current and potential coastal wetland extents of the study area.
* Model short-term coastal inundation risk of present-day Hawaii from known floods from 2019 – 2021. These data will be used to generate risk indexes (e.g., low, medium, and high risk of inundation/flooding) which will be presented on a map.
* Assess the relationship between mean sea level height data from *in situ* tidal gauges to the sea surface height anomaly data.
* Produce a geodatabase housing model data inputs and outputs.

**Partner Overview**

***Partner Organizations:***

|  |  |  |
| --- | --- | --- |
| **Organization** | **Contact (Name, Position/Title)** | **Partner Type** |
| **County of Hawaii, Planning Department** | Bethany Morrison, Planner | End User |
| **State of Hawaii, Department of Land and Natural Resources** | Jackson Bauer, Trail and Access Specialist | End User |
| **Arizona State University, Center for Global Discovery and Conservation Science** | Dr. Haunani Kane, Professor; Dr. Gregory Asner, Director | Collaborator |

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

The County of Hawaii and State of Hawaii Department of Land and Natural Resources (DLNR) are currently relying on sea level gauges and rough sea level projections to guide coastal planning under the Shoreline Setback Plan. At present, the county requires new information to locate priority areas where sea level rise is going to be the highest and where associated new wetlands might also develop in order to help meet their planning and regulation requirements regarding wetlands protection. Having been introduced to NASA Earth Observations though previous partnership, the County of Hawaii aims to leverage these data to inform decision-making for its Climate Adaptation Plan.

**Earth Observations & End Products Overview**

***Earth Observations:***

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| --- | --- | --- |
| **Platform & Sensor** | **Parameter** | **Use** |
| **Jason-1 Microwave Radiometer, POSEIDON-2** | SSHA | NASA MEaSUREs 5-day sea surface height anomaly (SSHA) data from 2019 – 2021 were compiled for Hawaii Island, and used for the sea level inundation model. |
| **Jason-3 Advanced Microwave Radiometer, POSEIDON-3B** | SSHA | NASA MEaSUREs SSHA data from 2019 – 2021 were compiled for Hawaii Island, and used for the sea level inundation model as well as compared to tidal gauge data from Hilo and Kawaihae tidal gauges from 2016 – 2020. |
| **Jason-2 Advanced Microwave Radiometer, POSEIDON-3** | SSHA | NASA MEaSUREs SSHA data from 2019 – 2021 were compiled for Hawaii Island, and used for the sea level inundation model as well as compared to tidal gauge data from Hilo and Kawaihae tidal gauges from 2012 – 2016. |
| **TOPEX POSEIDON, Microwave Radiometer, Solid State Radar Altimeter** | SSHA | NASA MEaSUREs SSHA data from 2019 – 2021 were compiled for Hawaii Island, and used for the sea level inundation model as well as compared to tidal gauge data from Hilo and Kawaihae tidal gauges from 2013 – 2022. |
| **Terra MODIS** | SSTA | Group for High Resolution Sea Surface Temperature (GHRSST) daily sea surface temperature anomaly (SSTA) data from 2019 – 2021 were compiled for Hawaii Island and used as inputs for our sea level rise inundation model. |
| **Aqua MODIS** | SSTA | GHRSST SSTA data from 2019 – 2021 were compiled for Hawaii Island and used as inputs for our sea level rise inundation model. |
| **Aqua AMSR-E** | SSTA | GHRSST SSTA data from 2019 – 2021 were compiled for Hawaii Island and used as inputs for our sea level rise inundation model. |
| **CORIOLIS WINDSAT** | SSTA | GHRSST SSTA data from 2019 – 2021 were compiled for Hawaii Island and used as inputs for our sea level rise inundation model. |
| **NOAA-19 AVHRR-3** | SSTA | GHRSST SSTA data from 2019 – 2021 were compiled for Hawaii Island and used as inputs for our sea level rise inundation model. |
| **GCOM-W1 AMSR2** | SSTA | GHRSST SSTA data from 2019 – 2021 were compiled for Hawaii Island and used as inputs for our sea level rise inundation model. |
| **Sentinel-1 SAR** | Flood confidence | The Global Flood Mapper tool, a GEE application, utilizes data from Sentinel-1 SAR for rapid mapping of flood inundation extent. |
| **PlanetScope** | Surface reflectance | PlanetScope 3-meter resolution data was used  to validate derived training data for the WIP tool. This imagery was also used to derive multispectral indexes such as Normalized Difference Vegetation Index (NDVI) for use as inputs in the WIP model. |

***Ancillary Datasets:***

* National Oceanic and Atmospheric Administration (NOAA) Tides & Currents Stations – *In situ* data of tidal heights, between 2013 and 2022, around Hawaii Island from tidal gauges at the Hilo and Kawaihae stations for ground truthing current and past sea level rise anomalies.
* State of Hawaii, 10-m Digital Elevation Model (2013) – Assess land elevations on coastal and wetland areas in relation to sea level to utilize as inputs for the WIP tool and sea level rise inundation risk model.
* Hawaii Soil Atlas, Various Soil Attribute Data (2014) – University of Hawaii at Manoa has compiled and uploaded Natural Resources Conservation Service (NRCS) Hawaii soil survey data onto an easily accessible database. Atlas data will be used as inputs for the WIP tool and sea level rise inundation risk model.
* Hawaii Climate Atlas, Various Climate Data Sets (1978–2017) – University of Hawaii at Manoa Climate data is organized into a ready accessible database for climate data throughout the Hawaiian island chain. Atlas data will be used as inputs for the WIP tool and sea level rise inundation risk model.
* United States Fish and Wildlife Service National Wetlands Inventory – Database to assess currently delineated wetlands and wetland cover types for modeling wetland probability.
* NASA MEaSUREs Gridded SSH product – Harmonized dataset between various sea surface height observations derived from Jason-2 and Jason-3 for assessing sea surface height anomalies. This data was acquired for 2013-2022.
* NASA MEaSUREs GHRSST Global Foundation SST Analysis – Sea surface temperature dataset analyzed from SST data from GHRSST were compiled for Hawaii Island, analyzed for anomalies, and used as an input for our sea level rise inundation model. This data was acquired for 2013-2022.
* Global Flood Mapper – An open-source Sentinel-1 SAR Google Earth Engine application used to acquire flood index maps, for known flood dates between 2015 and 2022, on Hawaii Island.
* Hawaii Carbon Assessment Landcover Map (2007-2012) – GIS layer used to categorize landcover types around Hawaii, particularly for non-vegetated regions to indicate lava in the flood index maps.

***Modeling:***

* Wetland Intrinsic Potential (WIP) Tool (Contact: Meghan Halabisky, Remote Sensing and Geospatial Analysis Lab, University of Washington) – Model potential wetland locations with probability rasters

***Software & Scripting:***

* Google Earth Engine – Flood risk index data acquisition via Global Flood Mapper
* ArcGIS Pro 2.9.1 – Data acquisition, processing, and visualization for the WIP and sea level rise inundation risk models
* Python 3.10 – WIP tool data processing, sea level rise inundation risk model data acquisition, processing, and visualization. Built random forest model with scikit-learn package. Tidal gauge to SSH data processing and visualization.
* Google Colab – Tidal gauge data acquisition
* R 4.2 – WIP tool data processing and visualization
* RStudio 2022.02.3 – WIP tool data processing and visualization

***End Products:***

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| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Geodatabase of Data Layers, Coastal Wetlands, and Ranked Vulnerability of Historical Features to Sea level Rise** | Jason-1  Jason-2  Jason-3  TOPEX POSEIDON  Terra MODIS  Aqua MODIS  CORIOLIS WINDSAT  NOAA-19 AVHRR-3  GCOM-W1 AMSR2  Sentinel-1 C-SAR  PlanetScope | Our partners in the County of Hawaii and DLNR will use this geodatabase to update wetland delineations records, evaluate short-term sea level inundation risks, and evaluate the risks of historical sites. | N/A |
| **Hawaii Island Wetland Extent Maps** | PlanetScope | These maps will provide our partners with a current snapshot of the landscape potential for new wetland locations. These maps will support partners’ mitigation planning efforts for areas subject to rapid sea level rise. | N/A |
| **Hawaii Island Sea- Level Rise Inundation Risk Index Map** | Jason-1  Jason-2  Jason-3  TOPEX POSEIDON  Terra MODIS  Aqua MODIS  CORIOLIS WINDSAT  NOAA-19 AVHRR-3  GCOM-W1 AMSR2  Sentinel-1 C-SAR | Partners will be able to use this data layer to aid in identifying critical areas at risk of sea level rise inundation and guide the development of their Shoreline Setback Plan. | N/A |
| **Tutorial and Protocol Documentation** | N/A | These guides will allow our partner organizations to reproduce our analyses, particularly when future data becomes available. Tutorials enable partners to apply our algorithms and provide justifications for methodology choices. | N/A |

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

The County of Hawaii and State of Hawaii DLNR aim to utilize the maps that make up our studies geodatabase to guide coastal planning for its Shoreline Setback Plan. The data provided will aid in the decision-making process of prioritizing where our partners should focus their mitigation efforts on first. Furthermore, stakeholders will have the most up-to-date wetlands extent and sea level rise inundation risk maps, and the results from both can be evaluated together to identify potential new wetlands that will aid in critical areas planning.

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