**NASA DEVELOP National Program**

**Fall 2016 Project Proposal**

**NASA Ames Research Center**

**Elkhorn Slough Ecological Forecasting II**

Utilizing NASA Earth Observations to Understand the Effects of Sea Level Rise and Climatic Variation on Blue Carbon Sequestration, Marshland Extent, and Vegetation Health in California’s Elkhorn Slough

**Project Overview**

***Objective:*** To analyze and model marsh vegetation health, extent, and its capacity to sequester carbon under different scenarios of sea level rise, climatic patterns, and sediment supply levels in Elkhorn Slough.

***Community Concern:*** Elkhorn Slough, home to over 135 aquatic birds, 550 marine invertebrates, and 102 fish species, is a habitat for several endangered species, such as the southern sea otter, which has a higher density of mothers with pups in the estuary than anywhere else in the world. Furthermore, while the slough provides several important ecosystem services, including sequestering carbon, the slough currently faces very high nitrate and phosphate levels, along with low nighttime concentrations of dissolved oxygen in areas with long residence times. Such changes to water quality in the slough can lead to eutrophication, hypoxia, and the death of aquatic and terrestrial species.

In additional to water quality issues, Elkhorn Slough faces challenges in marshland health. About 50% of Elkhorn Slough salt marshes have been lost in the past 150 years. With the threat of increasing sea levels and salinity, marsh resilience and adaptation will prove to be paramount to the survival of this vital ecosystem.

***National Application Areas Addressed:*** Ecological Forecasting, Water Resources, Climate

***Study Location:*** Elkhorn Slough, CA, and surrounding sub-basins (within 5-mile radius)

***Study Period:*** March 1997 to March 2016; Forecasting to 2017.

***Advisors:*** Dr. Sherry Palacios (Bay Area Environmental Research Institute, NASA Ames Research Center), Dr. Juan Torres-Pérez (Bay Area Environmental Research Institute, NASA Ames Research Center)

***Source of Project Idea:*** A science advisor at the NASA Ames Research Center, Dr. Sherry Palacios, worked with the Elkhorn Slough National Estuarine Research Reserve (ESNERR) during her previous studies at Moss Landing Marine Laboratory. She provided DEVELOP with contact information for Dr. Kerstin Wasson, ESNERR’s Research Coordinator, and suggested collaborating on a project involving water quality, eelgrass, otter habitat, and eutrophication. Upon speaking with Dr. Kerstin Wasson and Charlie Endris, ESNERR’s GIS Specialist, it became apparent that these partners could benefit from a large-scale monitoring approach and historical analysis of Elkhorn Slough using NASA Earth observations.

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| Elkhorn Slough National Estuarine Research Reserve (ESNERR) | Dr. Kerstin Wasson, Research Coordinator; Charlie Endris, GIS Specialist; John Haskins, Water Quality Monitoring Specialist | End-User | Yes |
| USGS, Western Geographic Science Center | Dr. Kristin Byrd, Research Physical Scientist | Collaborator | No |

***End-User Overview***

***End-User’s Current Decision Making Process:***

In 2004, the Tidal Wetland Project (TWP) was established as an ecosystem-based management initiative in Elkhorn Slough. Today, this project is under the leadership of the Elkhorn Slough National Estuarine Research Reserve (ESNERR). Over 100 stakeholders are engaged in this initiative, including an advisory science panel and a decision-making team consisting of all those involved with the regulatory and jurisdictional authority of the estuary. The TWP is also engaged in an ambitious marsh restoration project, to be achieved by adding sediment to a former salt marsh that subsided to mudflat elevation due to diking. However, the TWP, with its 100 stakeholders, is lacking sufficient information about the optimal strategies for supporting marsh resilience at Elkhorn Slough.

ESNERR has collected (or will collect in the near future) *in situ* data that can be used as model inputs for MEM. These include suspended sediment concentrations (which amount to a few hundred samples taken over several months of one year), six static GPS transects of marsh elevation (accuracy within several millimeters), stem density, and canopy height measurements. These measurements can be used for MEM input requirements: elevation, peak biomass, and suspended sediment concentration.

***End-User’s Capacity to Use NASA Earth Observations:***

Elkhorn Slough National Estuarine Research Reserve (ESNERR)– Charlie Endris, ESNERR’s GIS Specialist, worked with MODIS data several years ago during an oceanographic project. However, he has never applied NASA Earth observations to marsh studies or restoration in Elkhorn Slough. Therefore, this project would build the capacity of ESNERR to supplement *in situ* marsh measurements with remotely-sensed measurements and modeled results. Researchers at ESNERR would be trained to use the models into the future, beyond the period of this collaboration.

***Collaborator & Boundary Organization Overview***

***Collaborator Support:***

USGS – Dr. Kristin Byrd has experience doing research in the slough and running the Marsh Equilibrium Model (MEM) in previous and current research projects. She will serve as an advisor for this model, and is willing to speak to the team as needed.

***Boundary Organization Dissemination:***

Elkhorn Slough National Estuarine Research Reserve (ESNERR) – Staff at ESNERR engage in science and conservation outreach through many different mechanisms. They produce Water Quality Report Cards that are disseminated online and at workshops, and these serve as user-friendly indexes to educate the public about the current state of the slough’s water. Marsh restoration is a critical priority of the TWP, which is the primary audience for this work. Finally, ESNERR hosts public workshops at the Moss Landing Marine Labs, and their most recent workshop was filled to capacity. ESNERR has requested that the project members present their findings and results to members of the TWP at the culmination of the project.

***Project Communication & Transition Overview***

***In-Term Communication Plan:***

The team will communicate with ESNERR at least three times throughout each term. The main POCs for this communication will be Brittany Zajic, the current Center Lead, Jenna Williams, the Assistant Center Lead, as well as the Team Lead of each respective term.

***Transition Approach:***

As in the first term, the team will visit ESNERR and associated stakeholders in Elkhorn Slough to review the project’s objectives and available datasets in the first few weeks of the term. Communication will remain robust throughout the term via email and telecons. Results and manuals produced from this project will be presented to ESNERR at the end of the term in an in-depth discussion of findings, accompanied by a question and answer period. Stakeholders in the TWP will be invited to converse about these results, and discuss best locations for future marsh restoration locations. All results will be disseminated to ESNERR via email and in person if possible. Software release will be required if the team chooses to pursue image analysis through Google Earth Engine.

**Letter of Support:** Elkhorn Slough National Estuarine Research Reserve (ESNERR), Dr. Kerstin Wasson, Research Coordinator.

**Earth Observations Overview**

***Earth Observations:***

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| --- | --- | --- |
| **Platform & Sensor** | **Parameter(s)** | **Use** |
| **Landsat 5 TM, Landsat 7 ETM+, Landsat 8 OLI** | Surface Reflectance, Normalized Difference Vegetation Index (NDVI) | Landsat imagery will be processed via Google Earth Engine to create a time series of Elkhorn Slough tidal marshland extent. Years of this time series will include large El Niño events (1997/1998, 2002/2003, 2009/2010, 2015/2016), compared to large La Niña events (1998/1999, 1999/2000, 2007/2008, 2010/2011). Marshland extent will be classified in Google Earth Engine, categorizing marshland types by varying degrees of vegetation (pickle weed) density. Additionally, if time allows, NDVI will be applied to these Landsat images to analyze the health of these tidal marshlands during selected years in Elkhorn Slough. These analyses will provide a historical perspective of marshland growth, reduction, and health in Elkhorn Slough, coupled with comparative analyses on the effects of climatic patterns on these variables. These methodologies will benefit ESNERR as they plan upcoming marsh restoration projects. |
| **Sentinel 2a MSI** | Bottom of Atmosphere reflectance | Sentinel 2a data will be used to compare marsh classifications with *in situ* observations in the slough for 2016. This imagery will act as a broader source of collection for slough dynamics, but at better resolution than Landsat imagery. This will ultimately help the end-user assess marsh extent in Elkhorn Slough at a finer scale. |

***Ancillary Datasets:***

ESNERR *in situ* data – suspended sediment concentrations, stem density and canopy heights (used for peak biomass model input), six transects of static GPS measurements (used for elevation model input) – model inputs

NOAA Digital Coast – land cover dataset, LiDAR elevation data – model inputs

California Department of Fish and Wildlife – aerial imagery– comparison and validation of satellite imagery land classifications

***Modeling:***

Marsh Equilibrium Model (POC: Kristin Byrd, USGS)

TerrSet Geospatial Monitoring and Modeling System Climate Change Adaptation Modeler (POC: James Toledano, Clark Labs/ Clark University)

***Software & Scripting:***

Google Earth Engine – Classification of Landsat images and application of indices to Landsat imagery

ENVI – Classification of Landsat images

ESRI ArcGIS – Classification of Landsat images

**Decision Support Tool & End-Product Overview**

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product(s)** | **Partner Use** | **Datasets & Analyses** | **Software Release Category** |
| Time Series Analyses of Elkhorn Slough Marshland Extent and Vegetation Health | ESNERR will be able to view temporal and vegetation health changes in marshland cover in Elkhorn Slough (during large El Niño and La Niña events between 1997 and 2016). This will help them better estimate what percentage of marshland has been lost due to climatic variation, and understand how pickle weed coverage is affected by such events. This will help inform them of potential marsh restoration sites in the future. | This time series will be created from a combination of Landsat 5, 7, and 8 imagery, along with Sentinel 2a and other available airborne datasets. These images will be processed through Google Earth Engine. This time series will span from 1997 to 2016, with particular attention to years with notable El Niño and La Niña events. The team will compare their findings to scenarios/ parameters used in the Marsh Equilibrium Model, which will estimate the amount of potential carbon sequestered in Elkhorn Slough. | 3 |
| Restored Marsh Scenarios: Marsh Equilibrium Model (MEM) outputs | Different scenarios (modeled after periods of high drought, periods of severe El Niño storms, and different rates of sea level rise and sediment concentrations) will allow the end-users to understand the potential effects of climatic variation and changes on the health of the slough. These outcomes will help estimate the potential of blue carbon (carbon sequestration potential of the ocean), and vegetation health within Elkhorn Slough. | This model will be run based on *in situ* data provided by ESNERR. It will be calibrated using the slough’s soil accretion rates. The format of the MEM outputs will be in graphs, Excel tables, and visualizations. | 1 |
| Marsh Equilibrium Model (MEM) Manual | This manual will be helpful for the end-users because it will allow them to run the model using updated parameters after the project has ended. | MEM inputs, outputs, and calibration will be documented and shared with ESNERR. | 1 |

***End-User Benefit:***

ESNERR will be able to use the products listed above in their management decisions regarding how to best respond to subsiding land within the slough, rising sea levels, and wetland restoration approaches. This will help them implement specific mitigation techniques into their current 5-year TWP, and continue to educate decision-makers and the public about marsh health in the slough. Additionally, the DEVELOP project will assess the “blue carbon” benefits of marsh restoration.

“The end-products from this work will be shared with our large group of TWP stakeholders at a meeting within a year of completion of the project. Moreover, the results will be used to inform decision-making: a better understanding of marsh function and drivers will shape our restoration project being conducted in 2017, and will shape our strategies to reduce stressors to make our existing marshes more resilient in the face of sea-level rise.” – Dr. Kerstin Wasson

**Project Timeline & Previous Related Work**

***Project Timeline:*** 2 Terms: 2016 Summer (Start) to 2016 Fall (Completion)

***Multi-Term Objectives:***

* **Term 1:** 2016 Summer (ARC) – Elkhorn Slough Ecological Forecasting I
	+ Several goals for this first term were to analyze Landsat 5, 7 and 8 images of eutrophication hotspots of the slough during highly eutrophic time periods, and create a time series analysis of these events using TerrSet’s Earth Trends Modeler. Additional objectives were to model land use change to 2020 using TerrSet’s Land Change Modeler. Finally, the team acquired data for the Soil and Water Assessment Tool (SWAT) and ran this model to assess potential sources of eutrophication in the sub-basins surrounding the slough. The team produced and disseminated a SWAT manual to the end-users. Communication occurred via an in-person visit, emails, and telecons throughout the term, and results were presented to the partners at the end of the term via a WebEx workshop.
* **Term 2 (Proposed Term):** 2016 Fall (ARC) – Elkhorn Slough Ecological Forecasting II
	+ This second term will focus on analyzing marshland extent change and vegetation health in response to notable El Niño and La Niña events, as well as understanding results from the Marsh Equilibrium Model (MEM). The team will assess the effects of different sea level rise, weather, and sedimentation scenarios on marsh vegetation resilience and carbon sequestration capabilities. If there is time, the team can then assess the results of MEM and compare them to results of similar parameters run in another model: TerrSet’s Climatic Change Adaptation Modeler. The team will continue to communicate with the end-users throughout the term via emails and telecons, and will disseminate all results via an online workshop at the end of the term.

***Related DEVELOP Work:***

Summer 2016 (LaRC) – Examining the Applicability of NASA Earth observations and Google Earth Engine to Monitor and Forecast Mangrove Health and Extent in the Florida Everglades

Spring 2016 (MCHD) – Monitoring Marsh Conditions in Coastal Alabama Using NASA Earth Observations to Support the Alabama Coastal Foundation’s Restoration and Conservation Initiatives

Fall 2015 (JPL) – Louisiana Ecological Forecasting: Using UAVSAR, AVIRIS and AirSWOT to Examine Historical Trends and Model Sediment Transport within the Wax Lake Delta, Louisiana, to Inform Coastal Restoration Efforts

Summer 2015 (ARC) – Mexico Water Resources: Utilizing NASA Earth Observations to Detect Factors Contributing to Hypoxic Events in the Southern Gulf of Mexico

Spring 2011 (ARC) – California Ecological Forecasting: Hyperspectral Biofilm Classification Analysis for Carrying Capacity of Migratory Birds in the South Bay Salt Ponds

**Notes & References:**

***Notes:*** The end-user has wanted to assess marshland extent and health, as well as run the Marsh Equilibrium Model, for some time. For this reason, they have specifically requested that this project focus on these items, as this research would greatly impact their decision-making processes related to the restoration goals of their current 5-year Tidal Wetland Project.

***References:***

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