Effects of Resolution on Multi-Temporal Remote Sensing of Wetlands: Towards a Wetland Vegetation Phenology Indicator

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Wetlands, such as those located in the Sacramento San Joaquin Delta, are currently experiencing ecosystem stress from natural and anthropogenically forced environmental change. It is important to discover new ways to monitor their changes and provide the science necessary to develop informed management procedures and mitigation strategies. Furthermore, observing wetland ecosystems is imperative because they are sentinels of global climate and local hydroclimate variation. Mapping vegetation phenology from remote sensing platforms has been a successful indicator of ecosystem and environmental change in terrestrial environments. A similar metric for wetlands could enable researchers to better understand full impacts of environmental change. Currently, the satellite resolution requirements for such a metric are not well understood as wetland environments are much more spatially complex and temporally dynamic than terrestrial ecosystems, and current earth observing sensors may not be able to adequately capture these variations. This study evaluates the impacts sensor spatial and temporal resolution have on wetland plant functional type (PFT) mapping and phenology profile creation.

Here, detailed PFTs maps were created using 10-m and 30-m satellite images and through classification map comparison it was determined that both resolutions are suitable for mapping PFTs. Phenology profiles for two wetland vegetation community types were created using a 10-m/5-day dataset and were compared to those created using a 30-m/16-day datasets. Temporal resolution tradeoffs were evaluated by comparing phenology profile shapes of different wetland sub-regions in the Delta. This study suggests increased temporal resolution is not always required for monitoring wetland phenology; however, cloud spatial bias is a concern. Phenology profiles differed greatly by wetland type even within the same PFT class, indicating that phenology metrics should be developed separately for different regions in the Delta. These findings provide a useful base for retrospective phenology analysis and important considerations regarding the development of a wetland phenology indicator.

Student Award Competition: Yes

Keywords: Wetland, Phenology, Remote Sensing, Sentinel-2, Landsat 8, Indicator, Resolution

Poster Topic Data and Tools

Applications of UAS (Drones) for Aerial Mapping for Shoreline and Wetland Restoration and Management

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Small unmanned aircraft systems (sUAS; popularly known as “drones”), offer a variety of aerial mapping, imagery, and data collection capabilities with useful applications for shoreline and wetland restoration and management. Low-altitude aerial photogrammetry provides high-resolution digital elevation models, orthorectified images, and topographic contour maps at a fraction of the cost of traditional piloted aircraft surveys and ground-based techniques, allowing for monitoring of shoreline stability, vegetation changes, and impacts from sea-level rise. Key advantages of sUAS compared with other aerial and ground survey methods include reduced costs, allowing acquisition of data in less time with greater spatial and temporal resolution; access to difficult to reach or ecologically sensitive areas; and reduced risks to staff.

We present two recent case studies illustrating the benefits of drone imaging and surveying for wetland restoration, including determination of elevation changes, sediment volumes, slope stability and shoreline erosion under baseline conditions, during and after restoration. The first example is for the Montezuma Wetlands Restoration Project, a 2,400-acre dredged sediment disposal, management, and reuse site located in the Suisun Marsh. The project will allow the placement and reuse of dredged sediments from the San Francisco Estuary to restore approximately 1,450 acres of intertidal marsh, seasonal and managed wetlands, and shorebird habitat, and approximately 425 acres of transitional and upland habitat. The second study is for the Aramburu Island Ecological Enhancement Project in Richardson Bay. Created from dredge spoils and fill in the early 1960s, the 17-acre island became dominated by invasive, non-native plants, with shoreline erosion of up to 6 feet/year. Completed in 2012, the restoration project has the goal of converting unstable and degraded artificial habitat to enhanced terrestrial and intertidal habitat designed to achieve gradual dynamic transition during sea-level rise, and to reduce shoreline erosion using soft engineering conducive to shorebird and seal habitat use.

Keywords:	drone, photogrammetry, restoration, habitat, sea level rise, dredge, erosion, monitoring
Poster Topic	Data and Tools

Adapting to Rising Tides (ART) Bay Area Sea Level Rise Analysis and Mapping Project: Locally-Refined Maps to Support Sea-Level Rise Adaptation Planning

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In 2011, the Bay Conservation and Development Commission (BCDC) and the National Oceanic and Atmospheric Administration (NOAA) partnered with local, regional, state and federal agencies to conduct an adaptation process in Alameda County. That project, the Adapting to Rising Tides (ART) Alameda County project, developed a number of tools, processes, findings and recommendations applicable to the region. One example is the ART Bay Area SLR Mapping and Analysis tool, which was developed in response to challenges that the ART Alameda County Working Group members and project team had with regional scale sea level rise models. In response, the ART team, working group and AECOM developed maps that identified shoreline type for each 100-foot segment of shoreline, tidal datum for over 900 locations along the shoreline and elevations of the shoreline, leveraging the FEMA San Francisco Bay Area Coastal Study. Other counties expressed interest in the tool and the ART Program partnered with the Metropolitan Transportation Commission to develop similar maps for each county. The ART maps are the most locally refined maps available for adaptation planning and made more so by the intensive local stakeholder review process. The maps include SLR and extreme tide combinations through a unique water levels approach that communicates both temporary and permanent flooding, which provides thresholds for action. The maps also identify low points on the shoreline that lead to inland flooding, allowing limited resources to be directed to the locations that pose the earliest risk to shoreline natural and built communities. This mapping methodology has already supported vulnerability assessments and adaptation planning efforts in four counties and helps support the CCMP Task 15-3: Support local government efforts to develop shoreline vulnerability assessments that include assessment of natural resources as an asset category. Milestone: By 2021, complete vulnerability assessments for all nine Bay Area counties.

Keywords: Sea level rise, adaptation, community and ecosystem resilience

Poster Topic Data and Tools

New Carbon Offset Methodology to Quantify Greenhouse Gas Emissions Reductions from the Restoration of California Deltaic and Coastal Wetlands

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Cultivation of peat soils in the Delta contributes disproportionately to greenhouse gas emissions (GHG) in California relative to agriculture on low-organic matter soils. Since Delta islands were first diked and drained for agriculture in the late 1800s, more than 3.3 billion cubic yards (2.5 billion m^3) of organic soils have disappeared. Islands with elevations as low as 20–25 feet (6–7.5 m) below sea level represent a significant opportunity for carbon sequestration. At the same time, they represent an increasing risk of levee failures that threaten the very farmland and water conveyance systems the levees are built to protect.

A new protocol for restoration of wetlands for the Sacramento-San Joaquin Delta, San Francisco Estuary and in coastal areas of California has been adopted and represents a potential tool for implementing projects that generate offsets for the carbon market and foster increased sustainability. The protocol provides guidance for conversion of traditional agriculture to wetlands and rice cultivation. This conversion reduces GHG emissions by stopping oxidation and increasing storage of soil organic carbon, in addition to other benefits such as stopping or greatly reducing soil subsistence, decreased risks of floods, and improved habitat for migratory birds.

We analyzed three wetlands recently restored on Twitchell and Sherman islands. We quantified GHG emission reduction and financial income associated with the application of the newly adapted protocol. For the 300 to 800 acres (120-320 ha) wetlands, GHG emission reduction ranged from 2 to 9 t CO_2eq acre^{-1} year^{-1} (5-22 t CO_2eq ha^{-1} year^{-1}) and 500 to 7,500 t CO_2eq year^{-1} per wetland. The estimated maximum income was \$40 acre^{-1} year^{-1}. Results prove converting land from agriculture to wetland can highly reduce GHG emission and create a steady income for land owners, even when wetlands are a weak net GHG source.

Keywords: Carbon, wetlands, protocol, rice, agriculture, GHG emission, GHG mitigation, subsidence

Poster Topic Data and Tools

Modeling San Francisco Bay and Estuary: Climatology and 2014-2016 Warming Conditions

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A three-dimensional numerical modeling system for the San Francisco Bay is presented. The system is based on an unstructured grid numerical model known as Semi-implicit Cross-scale Hydroscience Integrated System Model (SCHISM). A regional coastal ocean model provides the lateral boundary condition. The SCHISM results from a decadal hindcast run are compared with available tide gauge observations, as well as a collection of observed temperature and salinity profiles.

The observed climatological annual mean salinities at the United States Geological Survey (USGS) stations shows the highest salinities to be in the open ocean and the lowest well north (upstream) of the Central Bay. The corresponding mean SCHISM salinities reproduced the observed variations with location quite well, though with a fresh bias. The corresponding observed mean temperatures within the Bay were 2 to 3^{o} C cooler in the Central Bay than to either the north or south. The surface atmospheric forcing and the heat flux at the western boundary are the two major terms in a SCHISM-based heat budget analysis of the mean seasonal temperature cycle for the Central Bay. In the Central Bay salt budget, freshwater discharged by rivers into upstream portions of the Bay to the north balanced by the influx of salt from the west are the primary drivers of the mean seasonal salinity cycle. The interannual variability in temperatures and salinity will also be examined, in particular the exceptionally warm water temperatures during 2014-2016. Concerning this warming, examination of observations and the SCHISM heat budget during this event suggests that the warming that developed during the second half of 2014 and early 2016 originated in the adjacent California coastal ocean and propagated through the Golden Gate into the Bay, indicating that such warming events may be predictable many months or even several seasons in advance.

Keywords: numerical modeling systems, interannual variability, freshwater discharge

Poster Topic Data and Tools

An Innovative Framework in Assessing Climate Change Impacts on Estuary Inflow

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The health of San Francisco Estuary's ecosystem largely relies on outflow from the Sacramento-San Joaquin Delta which in turn is influenced by the State Water Project (SWP). Climate change induced changes in precipitation, warming, and Sea Level Rise (SLR) will change the amount of streamflow entering the Delta and Estuary, the timing of that streamflow, and the salinity and ocean boundary conditions of the Estuary. The goal of this study is to assess the impacts of those potential changes in precipitation, temperature, and sea level on critical operational metrics including annual SWP deliveries, Lake Oroville storage, and seasonal net Delta outflow. An innovative bottom-up decision scaling approach is adopted for this purpose. The approach identifies possible variation ranges of climatic variables from downscaled Global Circulation Model (GCM) projections. Specifically, the potential range of temperature change is explored by increasing mean temperature in 0.5°C increments from 0°C to 4°C (nine scenarios). Potential change in precipitation is explored from -30% to 30% in 10% increments (seven scenarios). Three SLR conditions are considered, no rise, 15 cm rise, and 45 cm rise. A hydrologic model and a water system model are run sequentially to simulate aforementioned operational metrics under those climate change scenarios. Model results indicate that both SLR and warming would reduce SWP annual deliveries. While SLR shows no clear impact on Lake Oroville storage, warming would lead to declined storage. As expected, increasing (decreasing) precipitation would increase (decrease) SWP annual deliveries and Lake Oroville Storage. Increases (decreases) in precipitation also increase (decrease) seasonal net Delta outflow. However, warming shows nonhomogeneous (across different warming scenarios in different seasons) impacts on net Delta outflow. Compared to warming, SLR exhibits less significant impact on net Delta outflow.

Keywords: Estuary, decision-scaling, climate change, State Water Project, inflow

Poster Topic Data and Tools

Seasonal Variability of Salinity and Stratification Dynamics in Lower South San Francisco Bay

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Lower South San Francisco Bay (SSFB) is characterized by tidal excursions that are comparable to its length, resulting in strong coupling between the central part of the embayment and its perimeter. At a channel station in Lower SSFB, a combination of CTDs and ADCPs were deployed to measure profiles of salinity and velocity from September 2015 through February 2017. This period spanned two winter seasons, but included a relatively dry winter (2015-16) and an exceptionally wet one (2016-17).

In this poster, we will show salinity and hydrodynamic variability comparing a dry period (fall 2015), a weak rainfall winter (January 2016) and a strong rainfall period (February 2017). Comparing these three periods we observe traditional longitudinal strain-induced periodic stratification (SIPS) during the first two periods, but modified by variable lateral circulation. The third period shows strong lateral exchange and counterintuitive salinity variability on the tidal timescale, which we attribute to lateral forcing from perimeter habitats. Together the observations suggest that the tidal influence of the perimeters on an estuarine channel has strong seasonal variability, due to the combined influence of longitudinal and lateral processes.

Student Award Competition: Yes

Keywords: hydrodynamics, seasonal variation, fieldwork, San Francisco Bay, stratification

Poster Topic Data and Tools

A Remote Sensing-Based Model of Tidal Marsh Aboveground Carbon Stocks for Greenhouse Gas Inventories and Climate Mitigation

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Remote sensing based maps of tidal marshes, both of their extents and carbon stocks have the potential to play a key role in conducting greenhouse gas inventories, implementing climate mitigation policies, and aiding coastal climate change adaptation decisions. Our goal was to generate a single remote sensing model of tidal marsh aboveground biomass and carbon that represents nationally diverse tidal marshes within the conterminous United States (CONUS). To meet this objective we developed the first national-scale dataset of aboveground tidal marsh biomass, species composition, and aboveground plant carbon content (%C) from six CONUS regions including San Francisco Bay. The final model, driven by six Landsat vegetation indices and with the soil adjusted vegetation index as the most important (n=409, RMSE=310 g/m^2, 10.3% normalized RMSE) successfully predicted biomass and carbon for a range of plant functional types defined by height, leaf angle and growth form. Model error was reduced by scaling field measured biomass by Landsat fraction green vegetation derived from object-based classification of National Agriculture Imagery Program imagery. We generated 30m scale biomass maps for estuarine and palustrine emergent tidal marshes as indicated by a modified NOAA Coastal Change Analysis Program map for each region. With a mean plant %C of 44.1% (n=1384, 95% C.I.=43.99% - 44.37%) we estimated mean aboveground carbon densities (Mg/ha) and total carbon stocks for each wetland type for each region. San Francisco Bay brackish/saline marshes had the highest C density of all estuarine emergent marshes across the six study regions (2.03 ±0.06 Mg/ha). The overall aboveground biomass carbon density of estuarine emergent tidal marshes in the six regions was 1.78 ±0.05 Mg/ha. This modeling and data synthesis effort will allow for aboveground C stocks in tidal marshes to be included for the first time in the 2018 U.S. EPA Greenhouse Gas Inventory for coastal wetlands.

Keywords: tidal marsh, climate mitigation, greenhouse gas inventory, remote sensing, biomass

Poster Topic Data and Tools

Inundation Patterns in the Delta Ecosystem during the 2016 Wet Season

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Periodic flooding events can give rise to a varied mosaic of aquatic habitats that would otherwise be dry. These episodically-available habitats include river floodplains, which are critical to many native fish species populations in the Central Valley. The Sacramento-San Joaquin Delta is one of the most modified estuaries in the world, with seasonal cycles of floodplain habitat availability fundamentally altered because of reduced inflow (because of dams) and spatial disconnection of floodplains and rivers (because of levees). And yet, during very wet years, some functionality is returned to the river-floodplain ecosystem because of flood bypasses and occasional levee breaks. The objective of this study is to document and characterize the increase in flooded habitat and connectivity during the rising arm and slow drawdown in habitat availability and loss of connectivity during the falling arm of the flood season using the 2016 wet season as an example. We will use monthly cloud-free Landsat data (30m pixel resolution, 7 bands) to track inundated area across the entire Delta. We will examine how changes in habitat availability after flooding vary across Delta regions. Understanding the spatial and temporal heterogeneity of flooded habitat, as well as the type of habitat that becomes available during wet conditions, will point to the potential regional impact of flooding for fisheries populations, as well as key limitations and opportunities for tidal wetland and floodplain restoration in the Delta.

Keywords: wet years, flooding, remote sensing, landsat, floodplain

Poster Topic Data and Tools

Bay Area Advanced Quantitative Precipitation Information Project

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The Advanced Quantitative Precipitation Information (AQPI) project, funded by a $19 million DWR Prop 84 grant, includes C-band and X-band radar units designed to observe low-level atmospheric rivers from the tropics responsible for more than 50% of Bay Area rainfall. Existing S-band radars, designed for Midwest thunderstorms, aim high and miss most ARs. Integrated will be modeling from a variety of federal, state and local agencies. Output will give end users precise information down to a square kilometer with respect to when rain will fall, the expected amount and intensity.

Keywords: water conservation, flood protection, climate change response, sea level rise

Poster Topic Data and Tools

NMFS NOAA/USFWS Biological Opinions and RPAs Data Dashboards and Decision Support

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Real Time Fisheries Decision Support: Accessing more than 48 disparate datasets, the Bay-Delta Live (BDL) decision support and data dashboards for fisheries provide the Delta Operations for Salmonids and Sturgeon and Smelt Working Group technical teams with a platform for visualizing, comparing and analyzing data from surveys and real-time monitoring. The support tools move beyond real time data analysis real-time data to real-time synthesis by providing an interactive and collaborative tool for developing and testing new hypotheses about fishery responses to water operations in the San Francisco Estuary.

Project Highlights: Data aggregation and web service development, data dashboard and visualization development, early warning indicators for fish migration, indices and data calculations, web and mobile access, customized application for random sampling designs, easy access to data for all stakeholders.

What Decisions Must Be Made: Real-time delta hydrologic operations decisions to protect endangered and threatened anadromous fish species. These management decisions for threatened and endangered species must be balanced with water supply and quality regulations in and South of the Delta.

Examples include:

-Use of the Sacramento Trawl, Sacramento Seine, and Knights Landing Catch Indices as indications of out-migrating salmonids to trigger a closure of the Delta Cross Channel Gates (NMFS BiOps Action IV.1.2).

-Monitor the Net Negative flows of Old and Middle River (towards the pumps) to reduce the likelihood of entrainment of fish species of management concern (NMFS BiOps IV.2.3).

Watch upstream environmental conditions (Flow and Water Temperature) as an indication of juvenile fish out-migration into the Delta (NMFS BiOps Action IV.1.1).

Keywords: Fisheries, decision support, operations, salmon, smelt, trawls

Poster Topic Data and Tools

Towards Measured Performance: Habitat Restoration Project Tracking, Assessment and Reporting

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Project Tracker (ptrack.ecoatlas.org) promotes regional capacity to track, assess and report on habitat restoration activities on a common interactive map in EcoAtlas. The development of Project Tracker was initially funded by USEPA and was a collaborative effort between the Sacramento-San Joaquin Delta Conservancy, San Francisco Bay and Central Valley Joint Ventures, U.S. Fish and Wildlife Service, California Departments of Fish and Wildlife and Water Resources, and the San Francisco Estuary Institute. This multi-agency workgroup guided the expansion of EcoAtlas, the State's repository for wetland project data, to include hundreds of additional habitat protection, enhancement, and restoration projects throughout the Central Valley and San Francisco Bay-Delta regions. Detailed qualitative and quantitative project data critical for natural resource managers – such as acres of distinct habitat types, species benefited, funding sources, and project progress towards its performance targets can now be consistently tracked across programs and regions throughout the State.

As new projects develop and existing projects enter new phases, project proponents can easily update associated information by using Project Tracker's online forms. Regional administrators can then, in turn, exercise review authority to ensure consistent data quality according to their own standards. This ability to view projects within the landscape context along with habitat resources, condition assessments, and other project activities provides the information needed for better planning and decision-making. EcoAtlas provides public tools for visualizing and querying project data; analyzing changes in habitat extent and condition; guiding landscape-scale conservation planning; prioritizing habitat restoration projects; evaluating progress towards meeting conservation objectives; building partnerships; and leveraging restoration resources.

By providing the tools needed to track and analyze landscape change and measure success of these efforts, we will improve our ability to report on public investments and conserve important habitats strategically well into the future.

Keywords: project tracking, customized regional reporting, habitat restoration, landscape-scale conservation planning

Poster Topic Data and Tools

Tidal Marsh Restoration Monitoring via Drone Data Analysis: A Case Study

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Monitoring tidal marsh restoration projects is time consuming and difficult. By nature, the conditions in tidal marsh habitats are challenging to work in, and the data collection poses inherent problems. Mapping vegetation establishment in patchy distributions results in various outcomes depending on the methods and individual conducting the work. Microtopographic relief of newly forming sloughs can be difficult to access and accurately measure. Moreover, once the habitats are more well-formed, sensitive species such as salt marsh harvest mouse may be present further complicating monitoring efforts. An emerging solution to all of these problems is using drones and their resulting high-resolution composite aerial photos for data analysis. This poster presents our methods and results on the East Bay Regional Park District's Dotson Family Marsh (Bruener Marsh) as a case study. A 20-minute flight captured several hundred overlapping high-resolution aerial images of the 100-acre study area. The images are then orthomosaically processed into a single, high-resolution, georeferenced composite aerial image and corresponding digital elevation model (DEM) with a vertical resolution of 2-3 centimeters. Remote sensing software can then be used to identify various signatures on the aerial image such as pickleweed plants, mud, and water. Once that data is imported into a GIS, mapping rules can be established to group individual plants into a vegetation community polygon to get accurate and repeatable results for estimating cover. The DEM can be used to identify new tidal slough formation. The extent of the sloughs and their depths can be compared from year to year to understand their change over time. Limited ground truthing is used to error check the results. All of this work can be done at a fraction of the cost of traditional field surveys and will only increase in accuracy and efficiency over time.

Keywords: tidal marsh, drone, pickleweed, monitoring, restoration, Breuner, UAV, gis, Dotson

Poster Topic Data and Tools

A Biogeochemical Modeling Study of San Francisco Bay

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In San Francisco Bay, the ecosystem is largely influenced by the phytoplankton and nutrient dynamics. This study investigates the temporal and spatial variabilities of chlorophyll, NH_4 and NO_3, which will facilitate the ecological management and fishery management in this region. Interannual variabilities will be first analyzed based on the observational data inside the Bay. Then, we will focus on each sub-embayment and study the major drivers for the phytoplankton growth and nutrient variations. To better understand this ecosystem, we will conduct a multi-year modeling study in San Francisco Bay. This model is based on Carbon, Silicate, and Nitrogen Ecosystem (CoSiNE) model and coupled with a Semi-implicit Cross-scale Hydroscience Integrated System Model (SCHISM). It is capable of modeling various water quality parameters in both ocean and estuaries. The model calibration in San Francisco Bay was already done by Liu et al. (2017). The same model setup will be used to investigate long-time ecological changes. The comparisons for chlorophyll and nutrients between model and observation will be presented. In addition, an updated version of CoSiNE model with a better model structure, a separate input file and new functionalities, will be introduced, aimed to facilitate the usage of this model in various water environments

Keywords: Ecosystem, CoSiNE model, phytoplankton, nutrients, biogeochemical modeling

Poster Topic Data and Tools