Incorporating the Coastal Blue Band into a Remote Sensing Toolkit for Mapping Intertidal Mudflats in South SF Bay [a]

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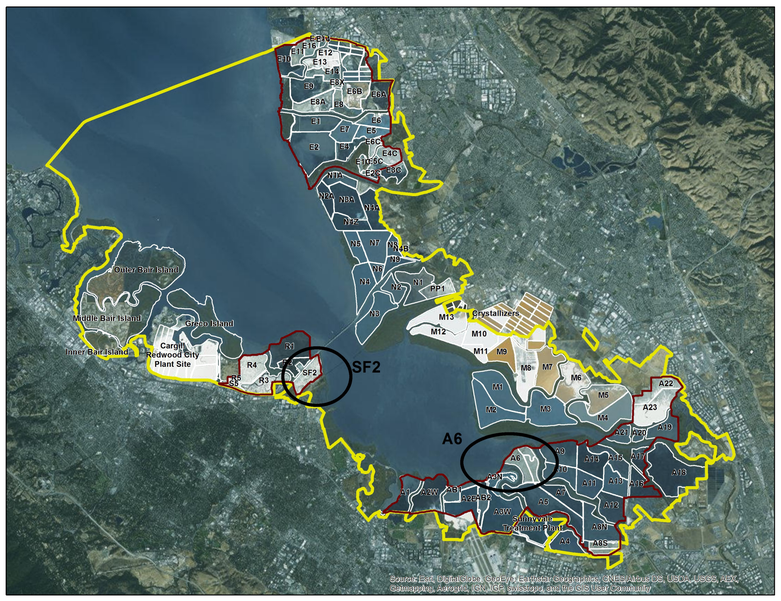
Background

One of the key uncertainties identified within the South Bay Salt Pond Restoration Project (SBSPRP) Adaptive Management Plan is whether the sediment source will come at the expense of critical mudflat habitat. If so, erosion of existing mudflats may result in changes in foraging area and food resources, thus reducing the ecosystem benefits of this habitat to waterbirds and other species. As a result, the SBSPRP requires methods for tracking changes to the distributions, extent and quality of mudflats within its expansive project area. A prior SBSPRP study (Fulfrost, et al. 2012) found that use of satellite imagery for tracking changes to approximately 2000 acres of mudflats was problematic because of the difficulty of matching a day and time when low tide (at Mean Lower Low Water) fully exposed the mudflats with satellite flyover. One impediment to tracking mudflats is that must be mapped while they are exposed at the lowest tides (mean lower low water, MLLW). The number of days that high resolution satellites, such as Ikonos, Landsat 8, or WoldView 2 or 3 pass over during MLLW limits the effectiveness of these resources for mapping. The inclusion of the Coast Blue Band (CBB) aboard WorldView 2/3 improves capabilities for mapping shallow water substrates

One key uncertainty identified within the South Bay Salt Pond Restoration Project (SBSPRP) Adaptive Management Plan is whether the use of mudflats as a sediment source for restoration will come at the expense of critical mudflat habitat. If so, erosion of existing mudflats may result in changes in foraging area and food resources, thus reducing the ecosystem benefits of this habitat to waterbirds and other species As a result, the SBSPRP requires methods for tracking changes to the distributions, extent and "quality" (as a food resource for foraging birds) of mudflats. One impediment to tracking mudflats using imagery is that they must be mapped while they are exposed at the lowest tides (mean lower low water, MLLW), due to restricted wavelength penetration in water for most sensors. An interdisciplinary team of scientists is developing a three step approach for mapping mudflats that is both cost effective and modular. As a first step, the USGS obtained a World View3 satellite image close to MLLW in Spring 2015 through the Commercial Imagery Derived Requirements Program (CIDR). In addition to the demonstrated potential of standard multispectral imagery to map exposed mudflats, the team will utilize the Coastal Blue Bird (CBB) to map shallow water mudflats. Mudflat boundaries derived from this image will be compared to existing high resolution LIDAR to delineate a baseline for tracking changes into the future. Second, we will explore the use of integrating Unmanned Aerial Surveillance (UAS) with commercial cameras outfitted with CBB filters for tracking mudflat extent and quality. Mudflat "quality" here refers to the presence (and density) of biofilm along the mudflat. Third, we will compare and asses the ability of both the satellite and UAS based CBB imagery to delineate mudflat distribution, extent and quality.

Study Area



Changes to mudflats need to be tracked in the entire SBSPRP study area, shown in yellow, but most importantly within the three SBSPRP restoration complexes (shown in red). This pilot study focuses specifically on mudflats in and around ponds already having undergone passive restoration, where changes to mud flats, and where changes to mudflat might have an impact on sedimentation in restored marshes as well as as a foraging resource for birds. These include:

(a) mudflats in and around **Pond A6 within the Alviso restoration complex**; and

(b) mudflats in and around **Pond SF2 within the Ravenswood restoration complex**

Management Need(s)

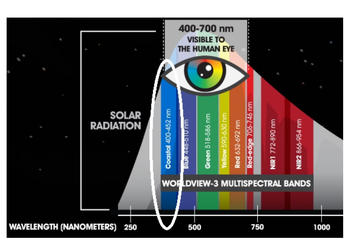
(1) **Delineate a mud flat "baseline"** to track changes

(2) **Tract Changes to the geographic distribution and extent of mud flats within the study area of the South Bay Salt Pond Restoration**
- minimum of 7 meter by 7 meter resolution = ~50 square meters

(3) **Map the"quality" of mud flats** (as a foraging resource for birds) by mapping the density and/or distribution of biofilm on the mud flats

Proposed Solution(s)

- Utilize *existing* high resolution Lidar (from USGS) and high resolution satellite imagery (eg Ikonos) - **to identify a mudflat "baseline"**
- Utilize Coastal Blue Band (CBB) aboard WorldView 2/3 (1.24 m multispectral resolution) – **to increase the effectiveness of mapping shallow water substrates in varying tidal conditions**.
- Utilize enhanced 8 band multispectral imagery aboard WorldView 2/3, including yellow, red-edge and 2 Near Infrared (NIR) bands, **to map distribution and density of biofilm on exposed mudflats**



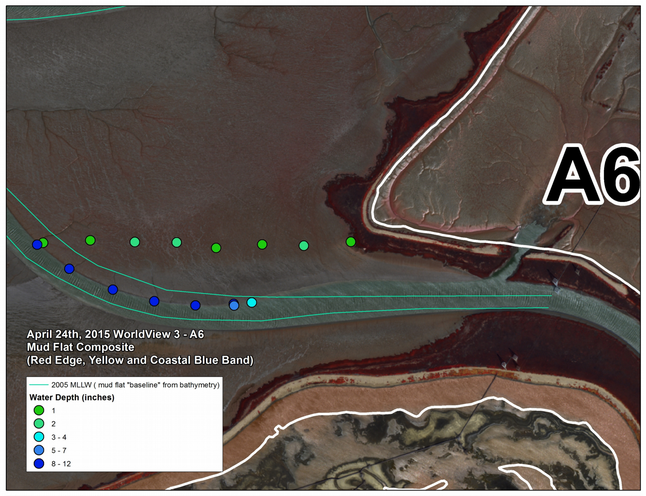
High Resolution Bands aboard WorldView3 includes the Coastal Blue as well as Yellow, Red-Edge and 2 NIR

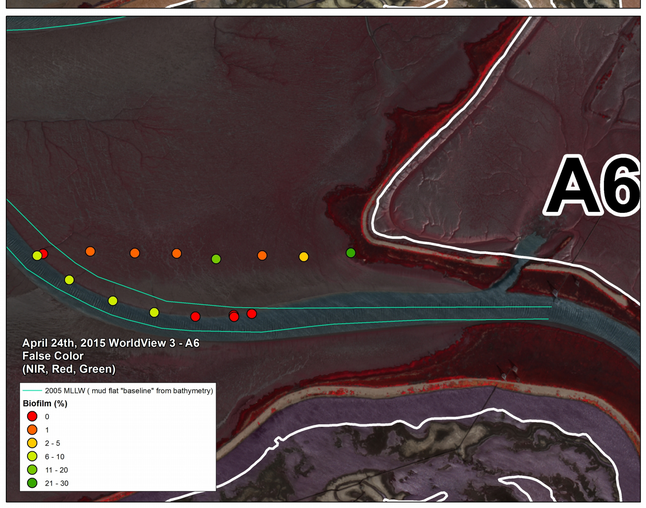
- Utilize modified Commercial Off the Shelf Technology (COTS) digital camer mounted on Unmanned Aerial Surveillance (UAS) – that include CBB and NIR – **to increase flexibility of monitoring intertidal mud flats for site specific (eg Pond A6) analyses**

Goals of Study - *completed*

(1a) Obtained WorldView 2/3 Imagery of plot study areas during Mean lower Low Water (MLLW)

- *obtained for free* via the USGS-CIDR agreement
- Using NOAA Tides and Currents *predicted* tide levels we identified 6 days in Spring/Summer in which MLLW occurs in or around Noon (the time of satellite flyover)
- Two WorldView3 images obtained (on 4/24/15 and 6/8/15)
  (a) 4/24/15 (12:08 PM) - predicted 0.18 above MSL (view angle 7 degrees off Nadir)
  - Obtained at 12:11 pm; *actual tide was ~ 0.4 ft above predicted*
  - View angle on 4/23 was not adequate (19 degrees off Nadir)
  (b) 6/7/15 – (10:58 am) – predicted -0.61 ft below MSL





(1b) Obtained Ground Truthing using sub meter GPS during time of satellite flyover
- On 4/24/15 (time of satellite flyover) and 5/9/15 & 5/23/15 (reference)
- presence/absence of mud flats,
- mud flat edge, water level, and presence/absence of biofilm

(1c) Images atmospherically corrected (FLAASH) and orthorectified

Goals of Study – *in process*

(2) Delineate mud flat "baseline" using existing high resolution Lidar and Imagery

(3a) Utilize Coastal Blue Band (CBB) to delineate geographic extent and area of mud flat
- Manual image interpretation techniques
- Automated image classification techniques (spectral and object oriented)
- Accuracy assessment using ground truthing

(3b) Compare to mud flat "baseline" and assess efficacy of techniques to track changes

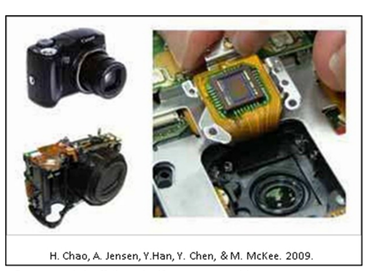
(4) Utilize 8 multispectral bands of WorldView 3 to map distribution and density of biofilm
- Compare to hyperspectral SpecTIR at Dumbarton Shoals
- Compare to field samples of biofilm at Dumbarton Shoals

Goals of Study – *next steps (unfunded)*

(5a) Modify COTS digital camera to include Coastal Blue Band (CBB) and Near Infrared (NIR)

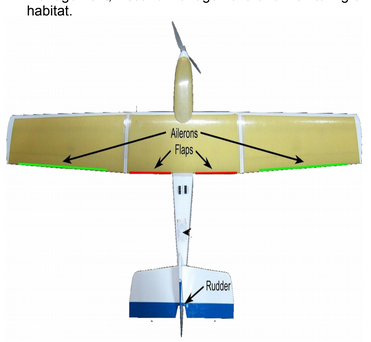
(5b) Mount modified COTS camera w/ CBB and NIR on Unmanned Aerial Surveillance (UAS)
- delineate distribution and extent of mud flat using processed imagery
- delineate distribution and extent of biofilm using processed imagery
- Compare (and calibrate) UAS/COTS derived mud flats (and biofilm) to imagery processed from WorldView 3

(6) Apply satellite and UAS based mud flats mapping techniques to entire SBSPRP study area
- seasonal variation
- multi-year variation



Commercial-off-the-shelf camera and image sensor. Camera could support Coastal Blue Band by replacing the visible light filter with a custom (400-450nm) narrow band filter

The AggieAir is a multispectral remote sensing unmanned aerial vehicle (UAV) that will be used as our sensor platform. Dr. Chen at UCMerced has access to the AggieAir and his lab has been successful at procuring 8 FAA Certificate of Authorizations. Aerial images from AggieAir has been used for many ecological applications such as agricultural water management, wetland management and monitoring of fish habitat.



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