Short Title: San Francisco Bay-Delta Water Resources

Subtitle: Utilizing NASA and ESA Earth Observations to Monitor Turbidity Conditions in the San Francisco-Bay Delta

VPS Title: The Delta Smeltdown: Monitoring Turbidity to Aid Delta Smelt Conservation

Project Team

Project Team:
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Project Overview

80-100 Word Objectives Overview:
Working with the Metropolitan Water District of Southern California (MWD), this project aims to study turbidity distribution within the San Francisco Bay-Delta. Water from the Bay is diverted through a system of dams and canals to be utilized for agricultural and municipal purposes, with pumping facilities in the southern portion of the Delta altering natural currents and sediment transport. In turn various species, including the threatened Delta smelt, are being carried southward or entrained. Because Delta smelt distribution is positively correlated with turbid waters, monitoring Bay-Delta turbidity may enable more efficient management of pump operations to ensure higher smelt salvage.

Abstract:
Water quality is a critical element of freshwater supply, particularly in times and areas of drought. Limited water resources can be further strained if water quality concerns are not effectively and efficiently addressed. While there are measures in place to protect human and environmental health from poor and risky water quality conditions, implementation of these measures is frequently reliant on physical water samples and fixed station data, both of which have gaps in spatial and temporal coverage of water quality conditions. This consideration is especially important in environments that are highly complex and heterogeneous, such as the San Francisco Bay Delta, as well as in budget-constrained areas or sites that are remote and are challenging to access. Remotely sensed information can help supplement existing data, supporting more informed water management practices and representing a wealth of information that has yet to be fully leveraged. In this project, we evaluated the application of remote sensing-derived turbidity from three Earth observing satellites in the San Francisco Bay-Delta and conducted comparisons with *in situ* turbidity data from USGS and CDEC water quality stations. The Semi-Empirical Single Band Turbidity Algorithm yielded a 1:1 relationship with in situ turbidity when calculated values were less than 15 to 20 FNU. This relationship did not extend to higher turbidity values, which yielded significantly lower slopes. Incorporating site-specific constants into the algorithm to correct for this deviation must be explored further. Sentinel-2 was the only satellite able to pick up turbidity values in the smaller tributaries of the Bay-Delta.

Keywords:
Turbidity, smelt, San Francisco Bay-Delta, water quality, Landsat 8, Sentinel-2, Sentinel-3

Partner Organizations:

Organization	POC (Name, Position/Title)	Partner Type	Boundary Org?
Metropolitan Water District of Southern California (MWD)	Dr. David Fullerton, Principal Resource Specialist, Dr. Shawn Acuna, Environmental Scientist, Russell Ryan, Senior Engineer	End User	Yes

Community Concerns:

- Prolonged drought conditions in California have necessitated an increased use of water resources from the Bay-Delta for both agricultural and municipal usage.
- Diverting water from this region must be done in consideration of the Delta smelt, an endemic and federally protected endangered fish species that spawns within the Bay.
- There is a need for remotely-sensed tools to monitor turbidity in areas not covered by *in situ* monitoring stations and to assist with turbidity model calibrations.

Current Decision-Making Practices & Policies:
Currently, Bay-Delta water quality assessments and management policies are primarily informed via field observations from *in situ* monitoring stations and sediment transport models to interpolate turbidity values between these fixed station sites. While Bay-Delta variations in salinity are well-understood, turbidity is less so. Data from these snapshots and models is currently necessary to balance water resource needs with proper ecosystem functioning. Turbidity distributions are a vital part in the MWD's decision-making process—determining the timing of pumping station operations and avoiding accidental entrainment of endangered species like the Delta smelt at pumping facilities. In addition, the MWD supports research efforts into the link between turbidity values and preferred smelt habitat, utilizing GPS tagging, drones, and other technologies to ensure compliance with local and federal wildlife protections.

Decision Support Tools & Benefits:

End Product	Earth Observations Used	Partner Benefit & Use	Software Release
Turbidity Maps	Landsat 8 OLI, Sentinel-2, Sentinel-3A	This product will be used for improved monitoring and management strategies for pumping facilities, such as pumping restrictions, periodic closure, or Delta smelt salvage at pumping facilities in the southern Bay-Delta.	N/A

Project Benefit to End User:
Enhanced accuracy of turbidity models will better inform water management strategies in the Bay-Delta. The MWD can use these models to increase delta smelt salvage and continuity of pumping operations to provide ample water-flow for municipal and agricultural purposes.

Project Details

Applied Sciences National Application Addressed: Water resources
Study Area: San Francisco Bay-Delta, CA
Study Period: April 2013 – June 2016

Earth Observations & Parameters:

Platform & Sensor	Parameter(s)	Use
Landsat 8, Operational Land Imager (OLI)	Turbidity (FNU)	Generating time-series turbidity maps
Sentinel-2 MSI	Turbidity (FNU)	Generating time-series turbidity maps
Sentinel-3 OLCI	Remote sensing reflectance (Rrs sr^{-1}); turbidity (FNU)	Generating time-series turbidity maps

Ancillary Datasets Utilized:

- California Data Exchange Center (CDEC) turbidity monitoring stations – Publically available *in situ* statewide water conditions dataset
- USGS Water Data turbidity monitoring stations – Publically available *in situ* nationwide water conditions dataset

Models Utilized:

- Anchor QEA Turbidity Model

Software Utilized:

- Esri ArcGIS – raster manipulation and analysis, image enhancement and map creation
- R – data processing, statistical analysis, and figure generation
- Python – data processing and analysis
- MATLAB – data analysis and figure generation
- ACOLITE – atmospheric correction and processing for Landsat 8 OLI and Sentinel 2
- SeaDAS – corrections and processing for Sentinel 3
- SNAP – Sentinel visualization and analysis
- Adobe Creative Suite – graphics, time-series turbidity animations

Project Handoff Package

Transition Plan:

During the last partner call (week 9 or 10), we will review our presentation for close out with our partners via WebEx. We will let them know the date they can expect to receive a LFT for all the items listed in the Handoff Package.

Project Continuation Plan: The Bay-Delta Water Resources project is scheduled for two subsequent terms at JPL. Our hand-off plan will involve leaving commented-out scripts and code in the proper DEVELOP format and providing an archive of data and images for the next team on physical hard drives left in the care of our science advisor.

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Partner POC: David Fullerton, dfullerton@mwdh2o.com

Handoff Package:

- Turbidity maps
- *In situ* vs. satellite comparisons

- Poster
- Presentation
- VPS video
- Technical paper