**NASA DEVELOP National Program**

**California – JPL**

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*Project Summary – Fall 2017*

**San Francisco Bay-Delta Water Resources II**

*Improving Water Quality Monitoring and Management in the San Francisco Bay-Delta Utilizing NASA Earth Observations in Association with the Delta Smelt*

**VPS Title:** Back to the Bay-sics

**Project Team**

***Project Team*:**

Alex Matacchieri (Project Lead), alexmat@udel.edu

Kate Cavanaugh

Carlos Reyes-Andrade

Lael Wakamatsu

***Advisors & Mentors*:**

Christine M. Lee (NASA Jet Propulsion Laboratory, California Institute of Technology)

David R. Thompson (NASA Jet Propulsion Laboratory, California Institute of Technology)

Glynn C. Hulley (NASA Jet Propulsion Laboratory, California Institute of Technology)

Kerry Cawse-Nicholson (NASA Jet Propulsion Laboratory, California Institute of Technology)

Michelle M. Gierach (NASA Jet Propulsion Laboratory, California Institute of Technology)

Erin L. Hestir (University of California, Merced)

***Past or Other Contributors*:**

Nick Tufillaro

Leah Kucera

Molly Spater

**Project Overview**

***Project Synopsis*:** This project aimed to study the turbidity distribution within the San Francisco Bay-Delta through remote sensing technology. Turbid waters in the Bay-Delta provide a favorable environment for the endangered delta smelt (*Hypomesus transpacificus*) to feed, and therefore, changes in turbidity affect this rare species. Therefore, to assess trends in the spatio-temporal dynamics of turbidity in the Bay-Delta, this study analyzed multispectral and hyperspectral data from the airborne instrument, ER-2 Airborne Visible Infrared Imaging Spectrometer (AVIRIS). Turbidity maps from Landsat 8 Operational Land Imager (OLI) and Sentinel-2 MultiSpectral Instrument (MSI) from last term were also evaluated.

***Abstract*:**

Water quality plays a critical role in California’s freshwater supply and environmental health in the San Francisco Bay-Delta. While there are measures in place to protect human and environmental health from poor 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. The Bay-Delta has high turbidity values, and optimal smelt conditions occur at 12 Formazin Nephelometric Units (FNU). However, during these periods of high turbidity, water export pumps shutoffs are triggered in order to minimize smelt entrainment. In partnership with the Metropolitan Water District (MWD), this project aimed to gain a better understanding of water quality through the use of remote sensing. The team used hyperspectral data from AVIRIS-NG, along with multispectral data from Landsat 8 OLI and Sentinel-2 MSI, in the San Francisco Bay-Delta from April 2013 to August 2017. *In situ* turbidity data from United States Geological Survey (USGS) and California Data Exchange Center (CDEC) water quality stations were compared against hyperspectral derived turbidity. This hyperspectral derived turbidity was also compared to derived turbidity from multispectral data. The spatio-temporal dynamics of turbidity in this region will provide insight as to how the environmental conditions impacting smelt are evolving. Consequently, the results of this analysis can be used to enhance turbidity monitoring and create efficient management plans that support the smelt.

**Keywords:**

Remote sensing, turbidity, water quality, San Francisco Bay-Delta, smelt, AVIRIS/AVIRIS-NG

***National Application Area Addressed:*** Water Resources

***Study Location:*** San Francisco Bay-Delta, CA

***Study Period:*** April 2013 – August 2017

***Community Concern:***

* Prolonged drought conditions in California have necessitated an increased use of water resources from the Bay-Delta for both agricultural and municipal usage.
* The delta smelt, an endemic and federally protected endangered fish species that spawns within the Bay, have a large influence on water operations in California.
* Turbid river inflows create a favorable environment for the smelt, resulting in strict pumping restrictions, periodic closure or high smelt salvage in the southern Bay-Delta.
* Remotely-sensed data will be utilized to monitor turbidity in areas not covered by *in situ* monitoring stations and to assist with turbidity model calibrations.

***Project Objectives:***

* Investigate the use of hyperspectral remote sensing data to characterize turbidity patterns in the San-Francisco Bay-Delta and compare it to *in situ* and multispectral data
* Generate time series maps that will improve monitoring and management of pumping facilities, in favor of the delta smelt

***Previous Term:*** 2017 Summer (JPL) – San Francisco Bay-Delta Water Resources

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **Metropolitan Water District of Southern California** | Dr. David Fullerton, Principal Resource Specialist Dr. Shawn, Acuna Environmental Scientist  Russell Ryan, Principal Engineer | End User | Yes |
| **34 North** | Amye Osti, Chief Executive Officer | Collaborator | No |

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

In order to monitor and manage the Bay-Delta while still adhering to water resources and ecological benefits, the MWD use *in situ* data at fixed locations and sediment transport models. The MWD monitors turbidity plumes as an indicator of smelt presence to protect the smelt from entrainment at pumping facilities. During the wet season, pumps are shut off once the turbidity exceeds the threshold over three days. Ultimately, the MWD aims to ensure a favorable habitat within the Bay-Delta for the smelt.

***Project Benefit to End User***:

By assessing the turbidity maps from the winter months, MWD will gain a better understanding of how this parameter affects the delta smelt. The maps will provide insight as to what changes in restrictions, closures, or salvages may need to be addressed and can be referenced in their future research on the smelt. This project will enable the MWD to utilize satellite information to improve future monitoring and management strategies.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter(s)** | **Use** |
| **ER-2 AVIRIS/AVIRIS-NG** | Remote sensing reflectance (Rrs, sr-1), Turbidity (FNU) | AVIRIS/AVIRIS-NG Rrs (10 m spatial resolution) will be used to derive turbidity maps in the Bay-Delta, with datasets collected since 2013 using MATLAB software. |
| **Landsat 8 OLI** | Remote sensing reflectance converted to turbidity | Landsat 8 Rrs will be used to derive turbidity maps in the Bay-Delta using freely available ACOLITE software. |
| **Sentinel-2 MSI** | Remote sensing reflectance converted to turbidity | Sentinel-2 Rrs will be used to derive turbidity maps in the Bay-Delta using freely available ACOLITE software. |

***Ancillary Datasets:***

USGS Water Data for the Nation – publically available turbidity monitoring station data, for the Bay-Delta validation data

California Data Exchange Center turbidity monitoring stations – publically available *in situ* statewide water conditions dataset

***Software & Scripting:***

MATLAB – derive turbidity from AVIRIS/AVIRIS-NG data following the approach of Fichot et al. (2015), derive turbidity from Landsat 8 OLI, and analysis and image generation for presentations and reports

Esri ArcGIS 10.5.1 – Create quality maps for presentations and reports

ACOLITE – atmospheric correction and processing for Landsat 8 OLI and Sentinel-2 MSI

R – data processing, statistical comparisons, figure generation

Adobe Creative Suite – graphics and turbidity time-series animations

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Products** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Turbidity Maps** | AVIRIS/AVIRIS-NG, Landsat 8 OLI, Sentinel-2 MSI | This will allow partners to develop improved monitoring and management strategies for pumping facilities, such as pumping restrictions, periodic closure, or delta smelt savage at pumping facilities in the southern Bay-Delta, most applicable during winter months and wet season. | I |

**Project Handoff Package**

**Transition Plan:**

During the final 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.

**Team POC:** Alex Matacchieri, alexmat@udel.edu

**Partner POC**: David Fullerton, dfullerton@mwdh20.com

**Handoff Package:**

* Turbidity Maps
* *In situ* vs. satellite comparisons
* Poster
* Presentation
* VPS video
* Technical paper
* Project summary

**References:**

Dogliotti, A. Ruddick, K., Nechad, B., Doxaran, D., & Knaeps, E. (2015). A single algorithm to retrieve turbidity from remotely-sensed data in all coastal and estuarine waters. *Remote Sensing of Environment*, *156*, 157-168.

Fichot, C. G., Downing, B., Bergamaschi, B., Windham-Myers, L., Marvin-DiPasquale, M., Thompson, D. R., & Gierach, M. M. (2015). High-resolution remote sensing of water quality in the San Francisco Bay-Delta Estuary. *Environmental Science and Technology, 50*(2), 573-583, doi:10.1021/acs.est.5b03518.