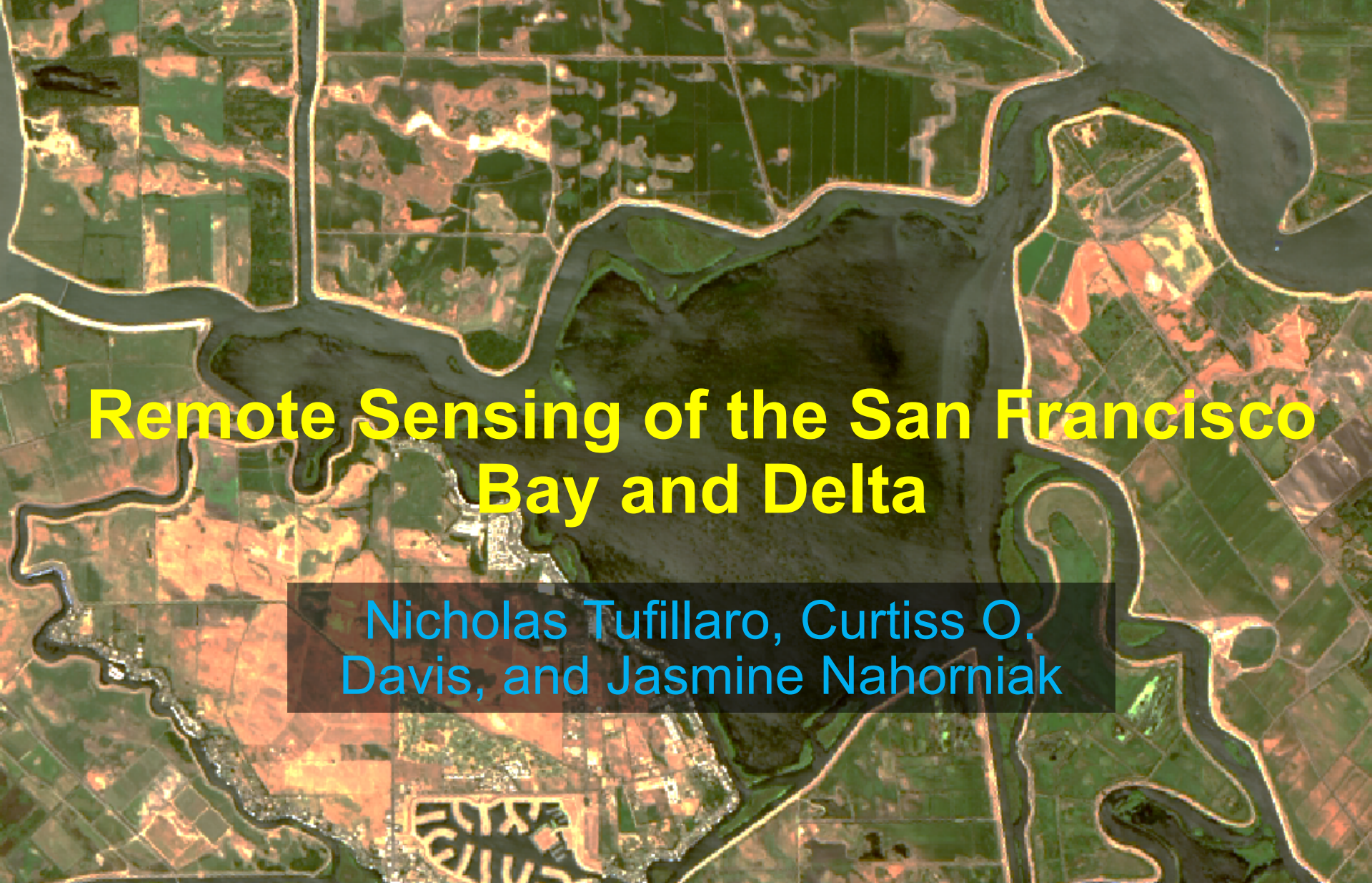

# Remote Sensing of the San Francisco Bay and Delta

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# Outline

Introduction

Water products from high spatial resolution land sensors:

- Landsat-8 (every 16 days, ~ 30 m) – open data
- Sentinel-2 (a, b, c, d …) (every 5 days, ~ 10 m) -- open data

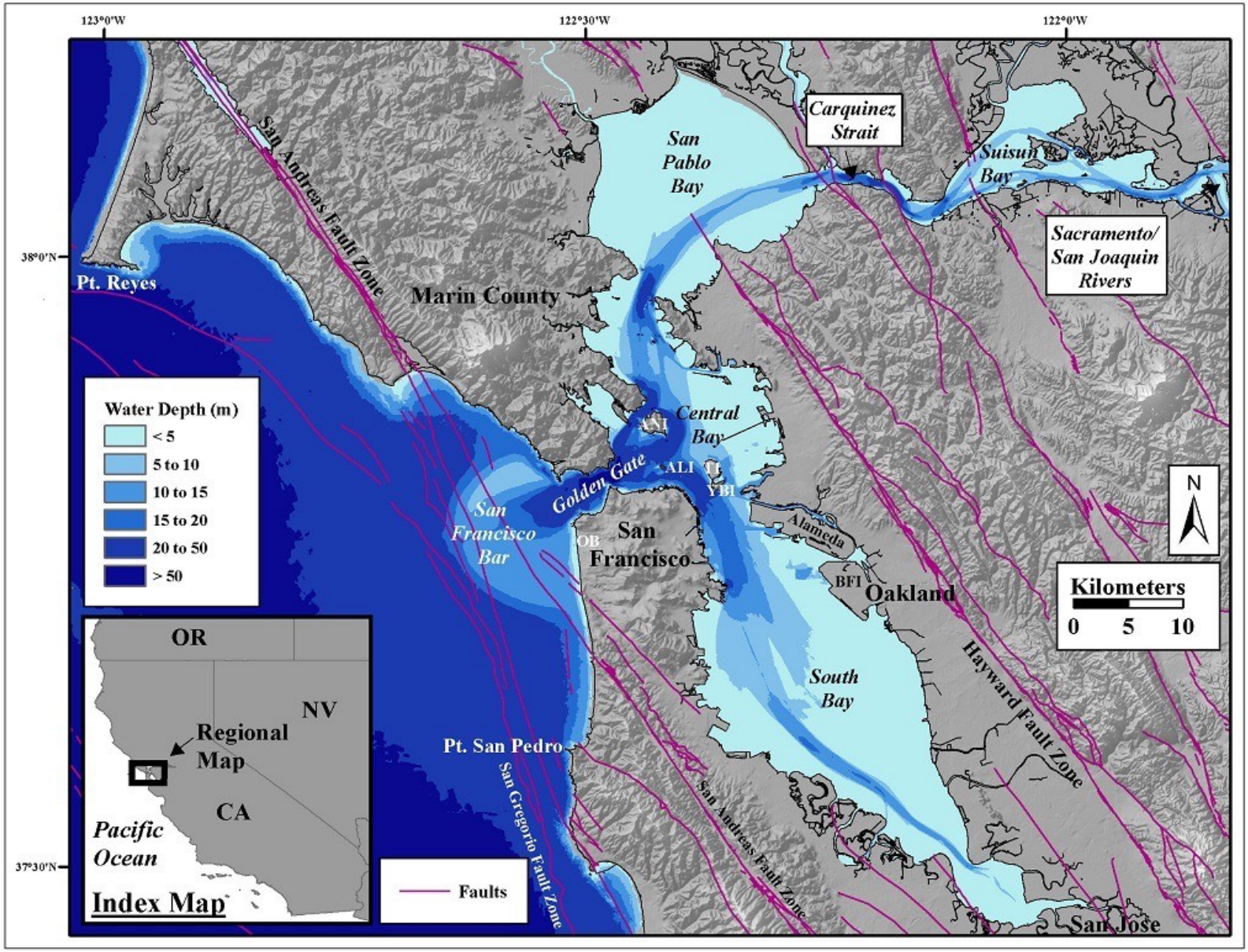
Examples

- Franks Tract
- Blooms

Future

- Land-water, Wetlands, Airborne
- Operational Products

# Landsat-8 and Sentinel-2 images of the North Bay



22 September 2016

# Landsat-8

# Landsat 8 OLI Characteristics

Landsat 8 Operational Land Imager (OLI)

Launched February 11, 2013

| Bands | Wavelength (micrometers) | Resolution (meters) |
|---|---|---|
| Band 1 - Coastal aerosol | 0.43 - 0.45 | 30 |
| Band 2 - Blue | 0.45 - 0.51 | 30 |
| Band 3 - Green | 0.53 - 0.59 | 30 |
| Band 4 - Red | 0.64 - 0.67 | 30 |
| Band 5 - Near Infrared (NIR) | 0.85 - 0.88 | 30 |
| Band 6 - SWIR 1 | 1.57 - 1.65 | 30 |
| Band 7 - SWIR 2 | 2.11 - 2.29 | 30 |
| Band 8 - Panchromatic | 0.50 - 0.68 | 15 |
| Band 9 - Cirrus | 1.36 - 1.38 | 30 |

**Landsat bands are optimized for land products and here we adapt them for coastal ocean products.**

# Landsat 8-OLI Processing Methods

Landsat-8 OLI San Francisco Bay Atmospheric correction uses an iterative SWIR method optimized for highly turbid waters (Vanhellemont & Ruddick 2014) using the 'Acolite' processor created by Vanhellemont and coworkers.

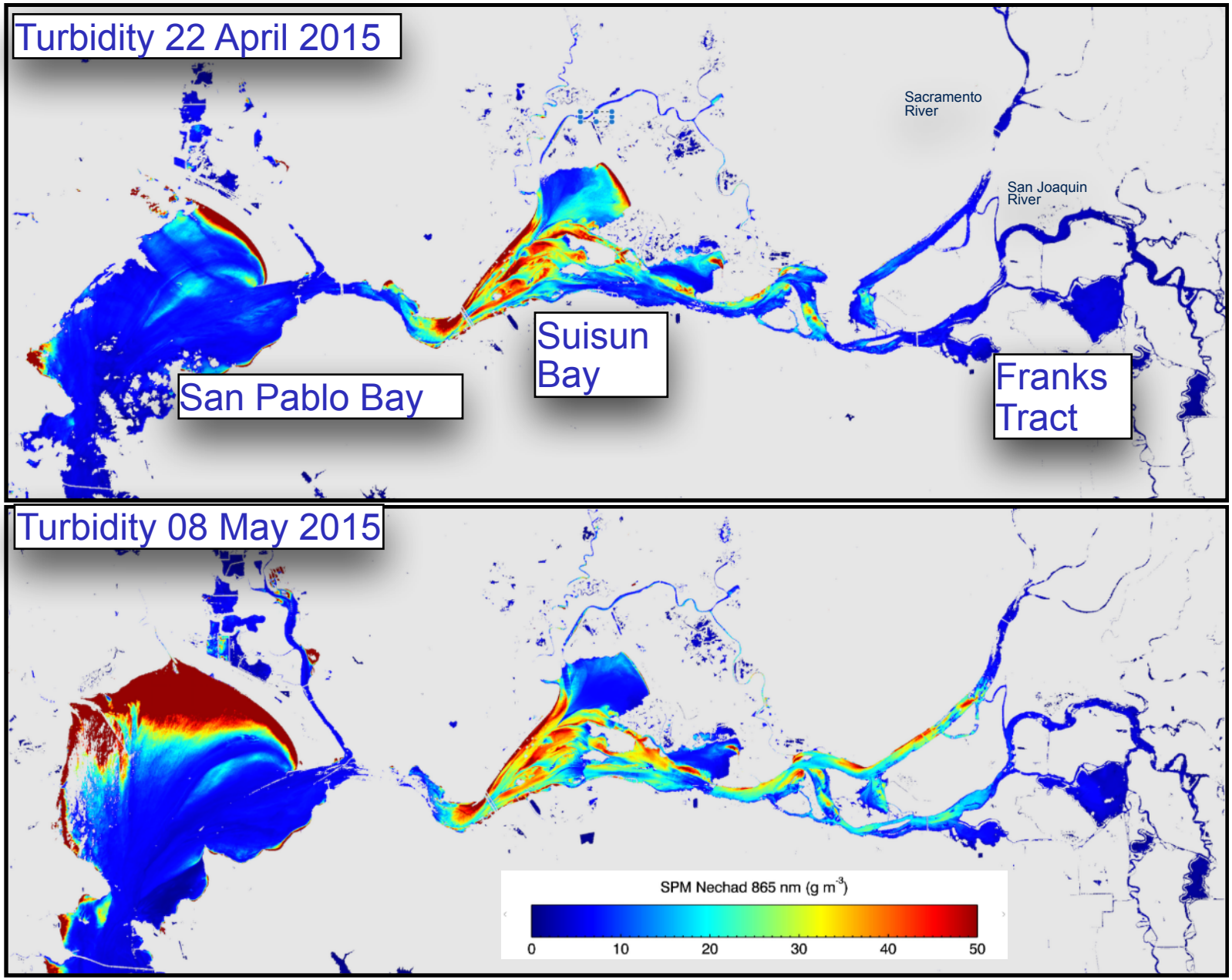
Total Suspended Sediment (TSS) maps (Nechad, Ruddick, and Park 2010) typically show an increase of turbidity in the lower Sacramento River and North San Pablo Bay. Product maps like these are used for the calibration and validation of the SFE model. The product maps are 'regionally tuned' using in situ observations.

Images are sharpened using the 15 m Panchromatic band.

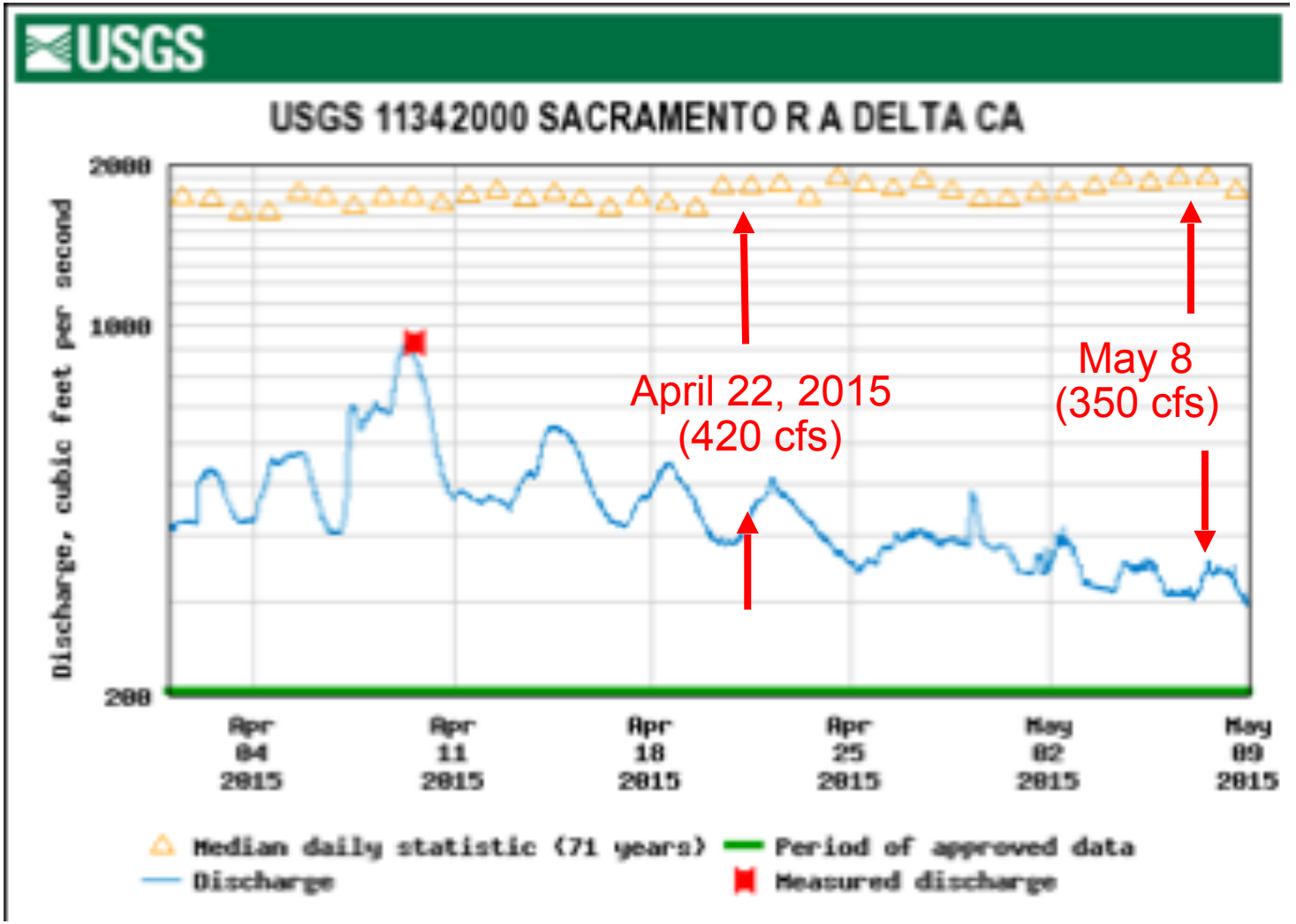
# Landsat-OLI image from 28 May 2014

- Landsat provides 30 m GSD, 16 day revisit, land bands and moderate SNR.
- 15 m Panchromatic band for image sharpening
- Especially good for the delta and adjacent land areas.
- Challenge to make good ocean products due to limited band set and low SNR for ocean scenes.

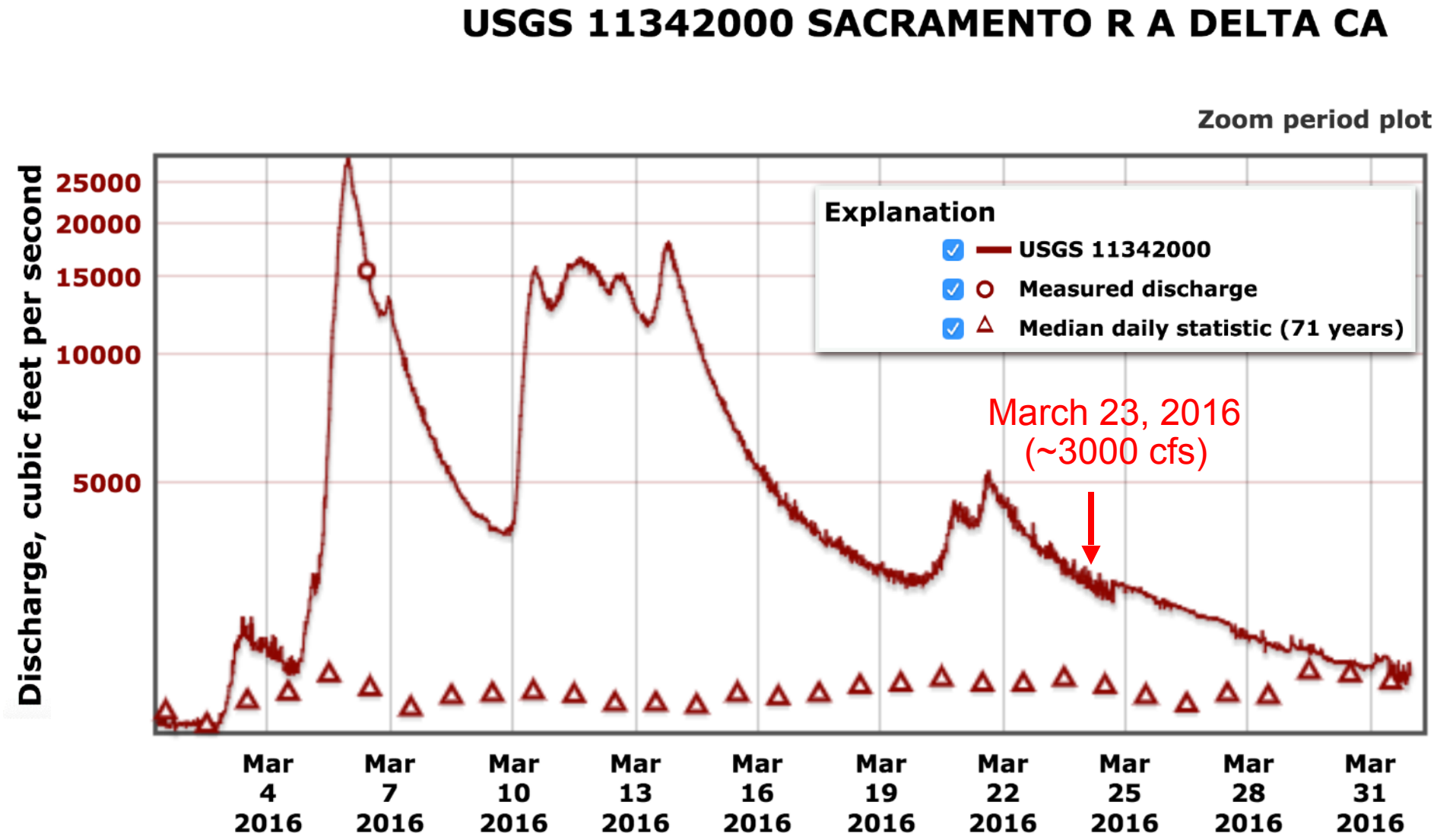
# SPM Maps from L-8 OLI data



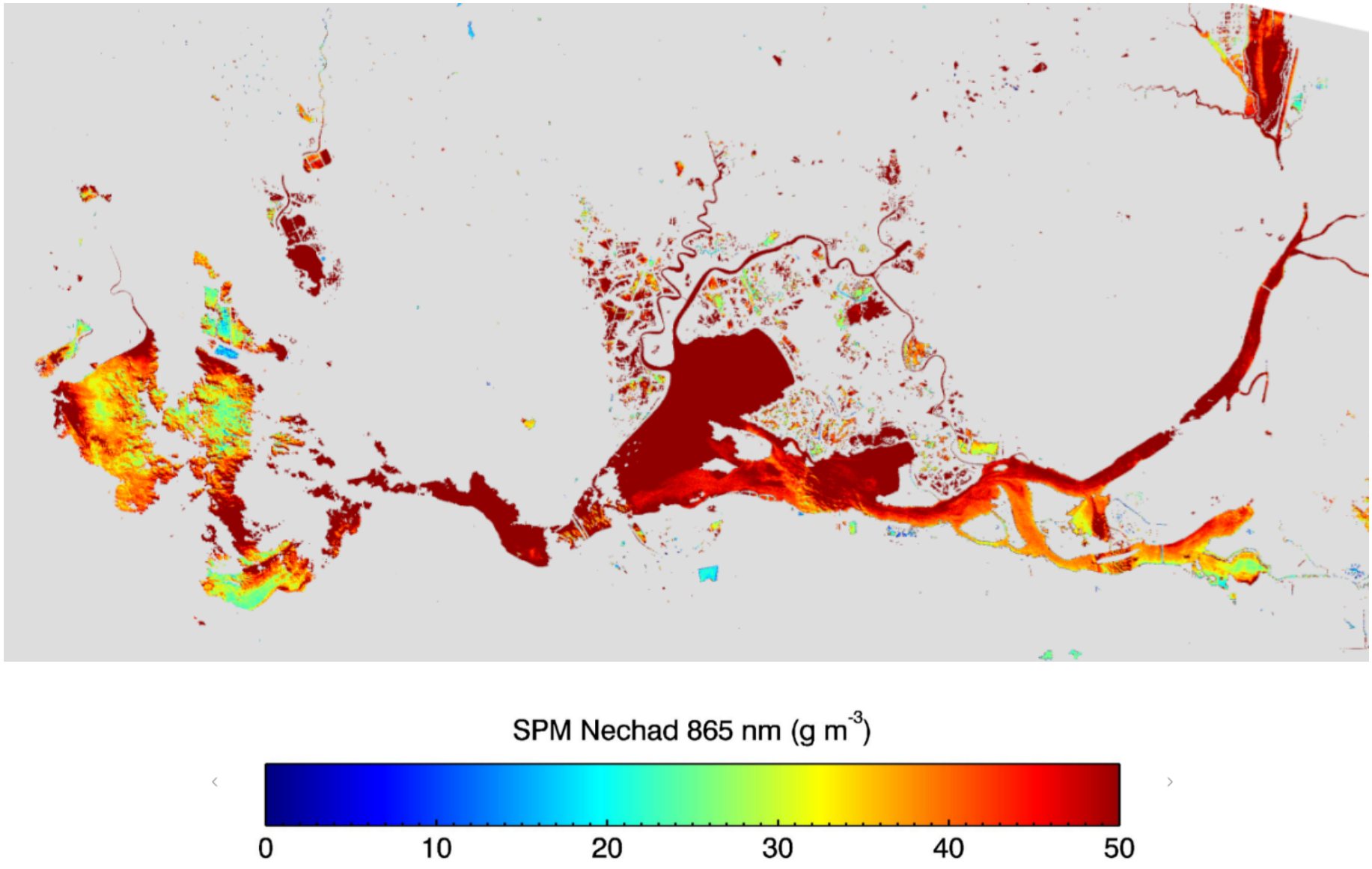
# Sacramento River Flows during the Drought



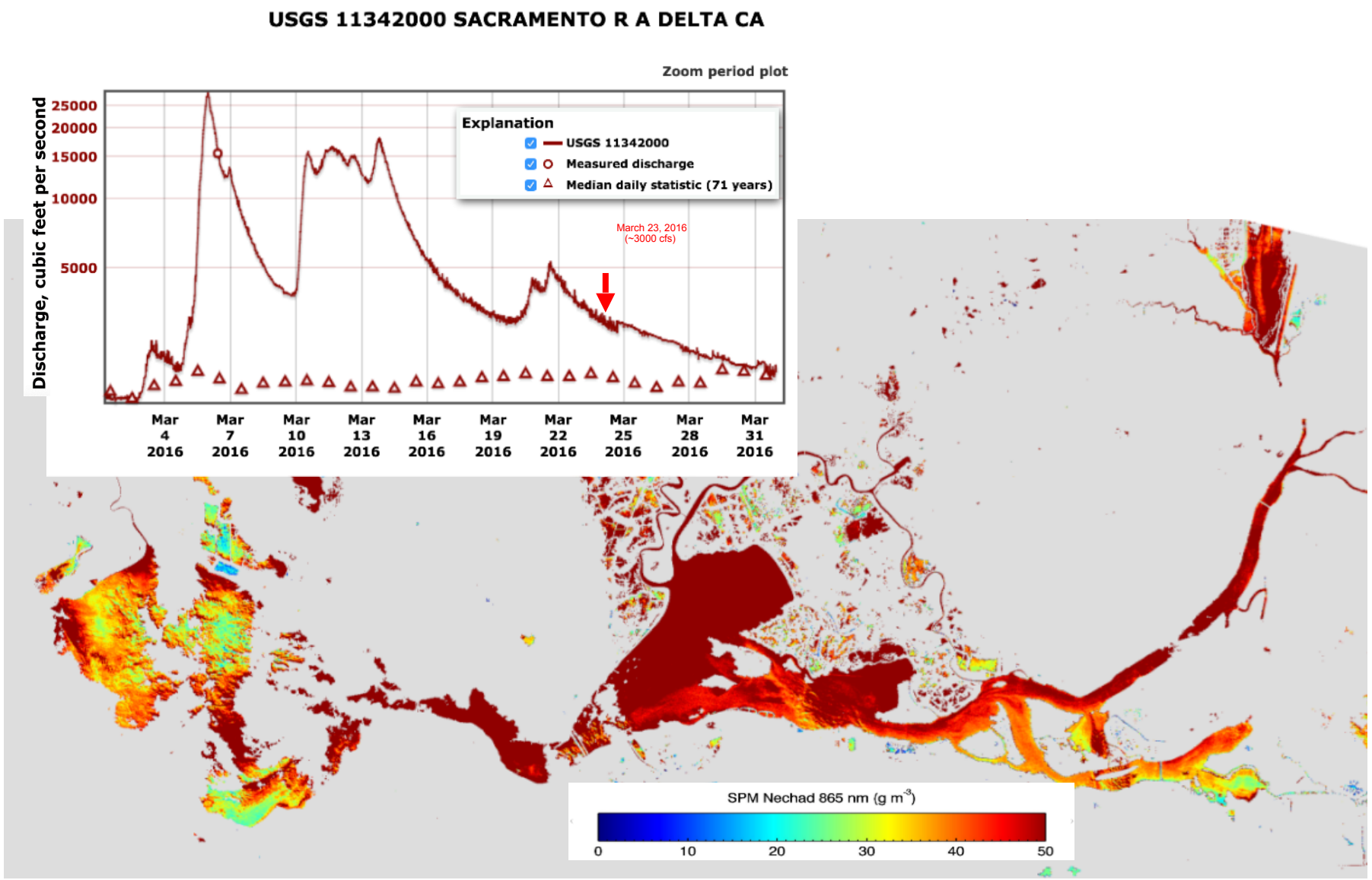
# The Miracle in March



# March 23, 2016 SPM



# Landsat March 23, 2016 SPM



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Images are sharpened using the 15 m Panchromatic band.

# Sentinel-2 (a)

# Sentinel 2 Bands — Even Better for Water

| Sentinel-2 Bands | Central Wavelength (μm) | Resolution (m) |
|---|---|---|
| Band 1 - Coastal aerosol | 0.443 | 60 |
| Band 2 - Blue | 0.490 | 10 |
| Band 3 - Green | 0.560 | 10 |
| Band 4 - Red | 0.665 | 10 |
| Band 5 - Vegetation Red Edge | 0.705 | 20 |
| Band 6 - Vegetation Red Edge | 0.740 | 20 |
| Band 7 - Vegetation Red Edge | 0.783 | 20 |
| Band 8 - NIR | 0.842 | 10 |
| Band 8A - Vegetation Red Edge | 0.865 | 20 |
| Band 9 - Water vapour | 0.945 | 60 |
| Band 10 - SWIR - Cirrus | 1.375 | 60 |
| Band 11 - SWIR | 1.610 | 20 |
| Band 12 - SWIR | 2.190 | 20 |

Spatial 10 Meters

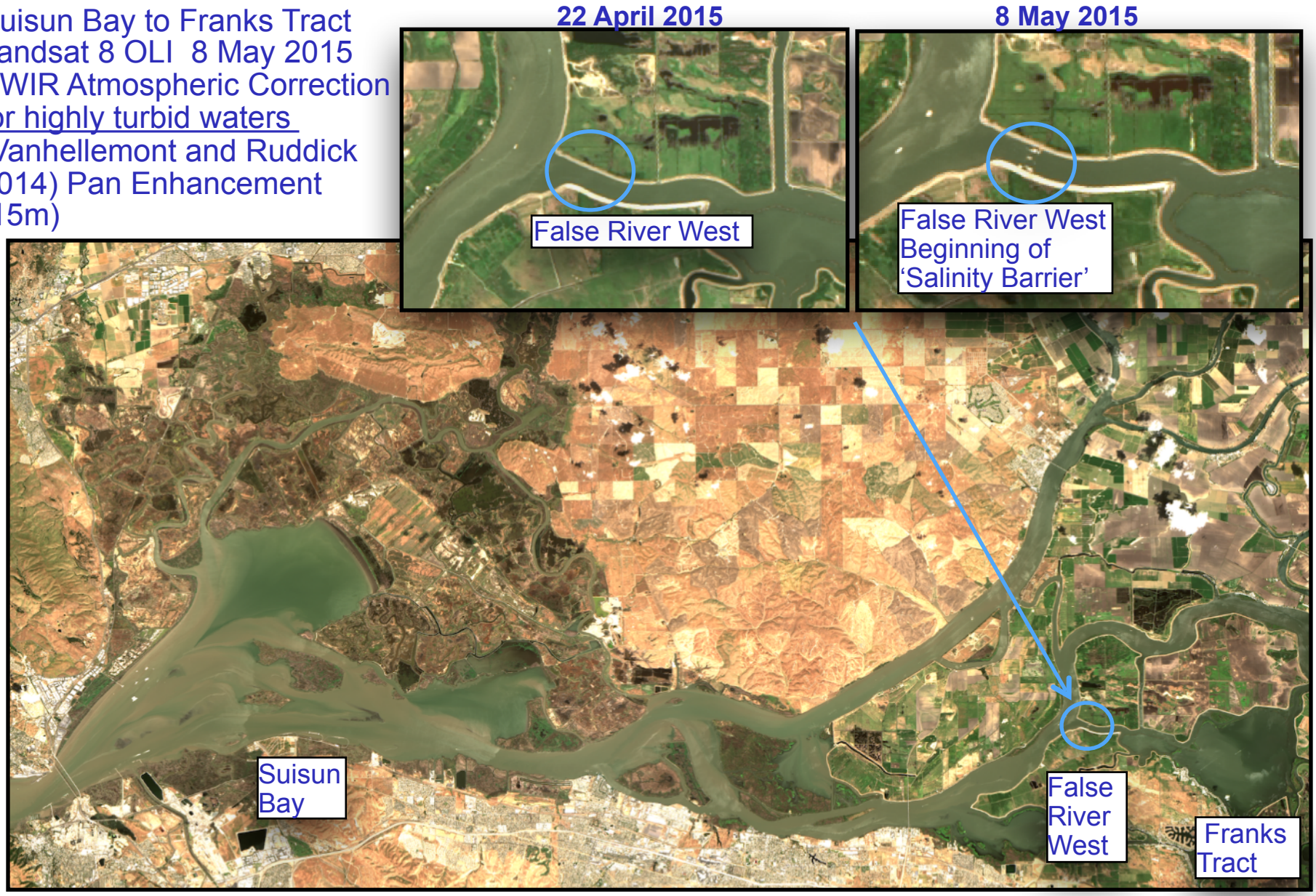
Spectral - Maximum Chlorophyll Index

# Suisun Slough Merges into Suisun Bay
# Sentinel-2: 30 March 2016

# Franks Tract

# Following the Franks Tract Salinity Barrier

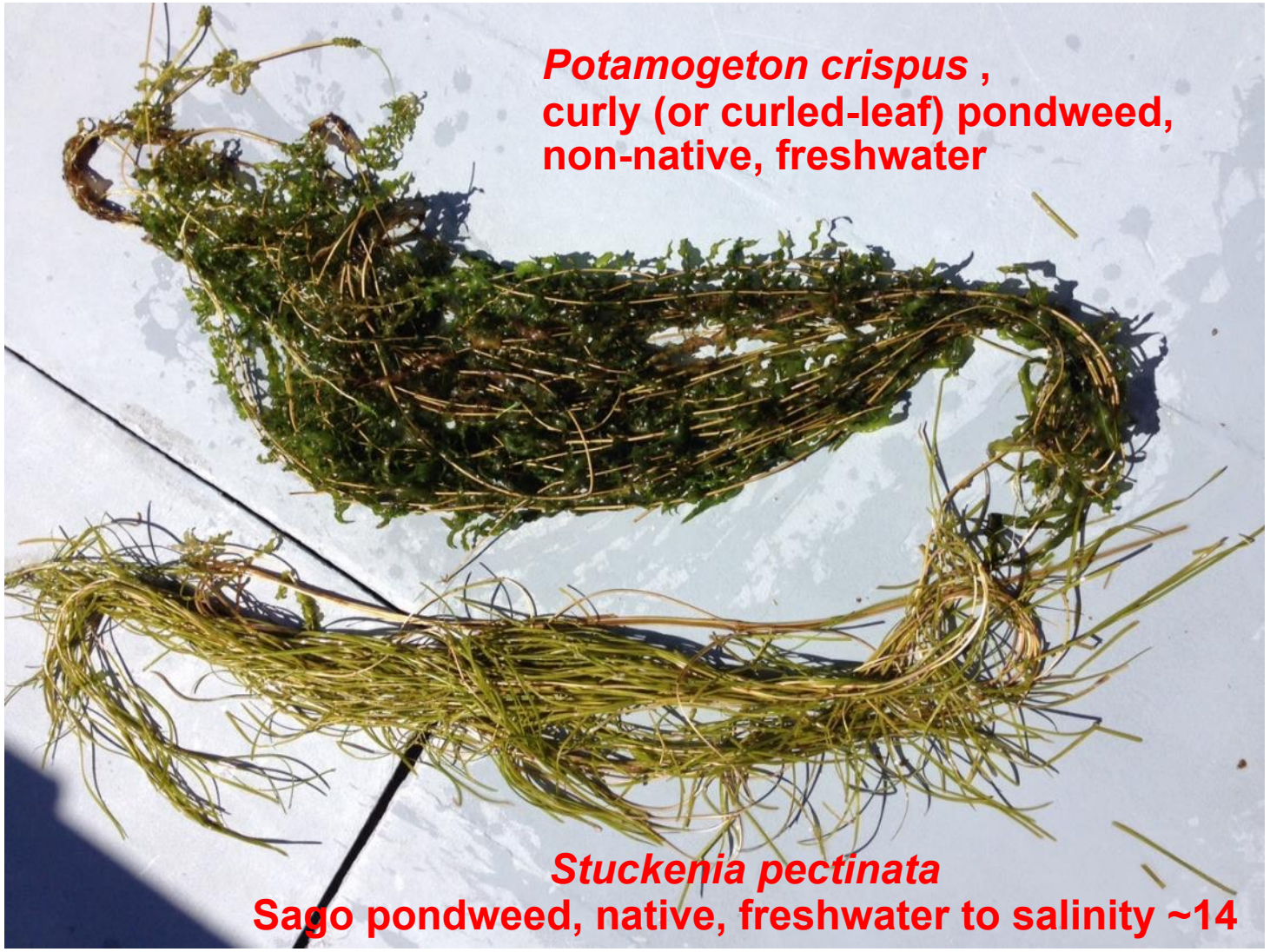
Suisun Bay to Franks Tract
Landsat 8 OLI 8 May 2015
SWIR Atmospheric Correction
for highly turbid waters
(Vanhellemont and Ruddick 2014) Pan Enhancement (15m)



# LS-8 OLI Franks Tract Aug 12, 2015

Macro Algae filling Franks Tract

# Sept 4. 2015 Franks Tract ship samples

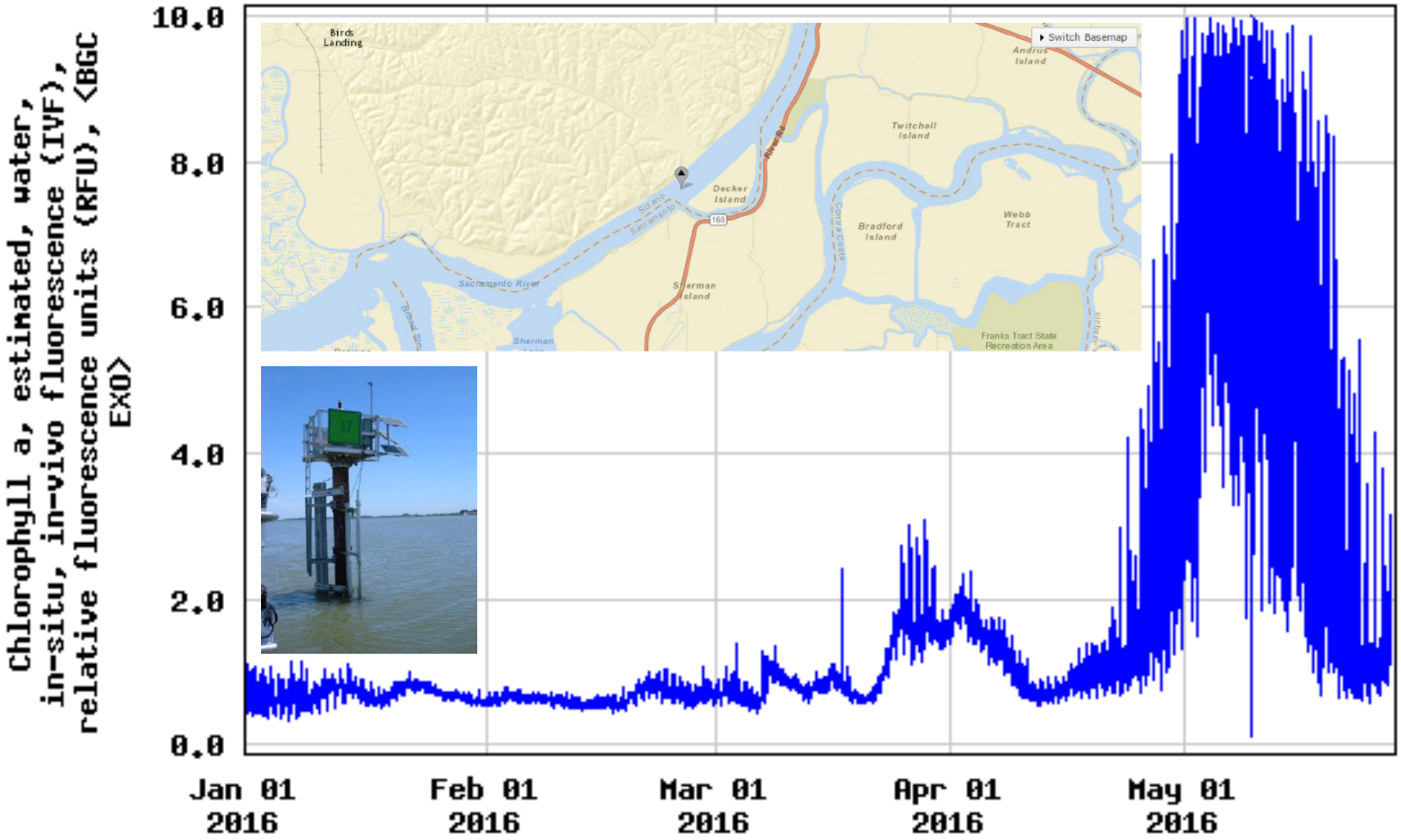



*ASlaughter, photo*

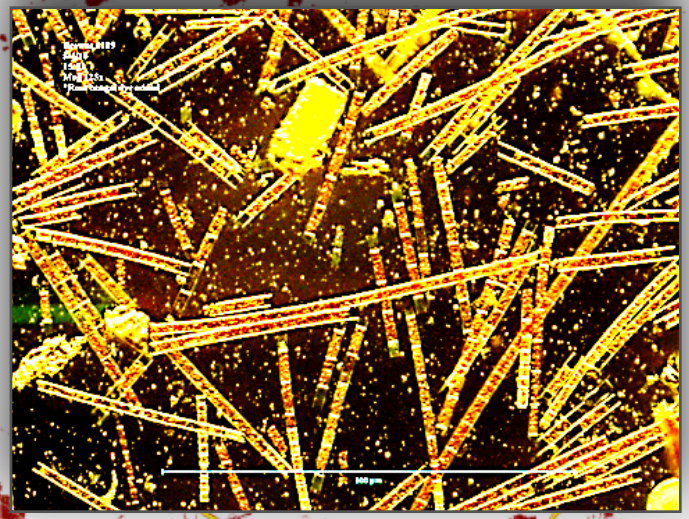
# Blooms

USGS

# USGS 11455478 SACRAMENTO R A DECKER ISLAND NR RIO VISTA CA

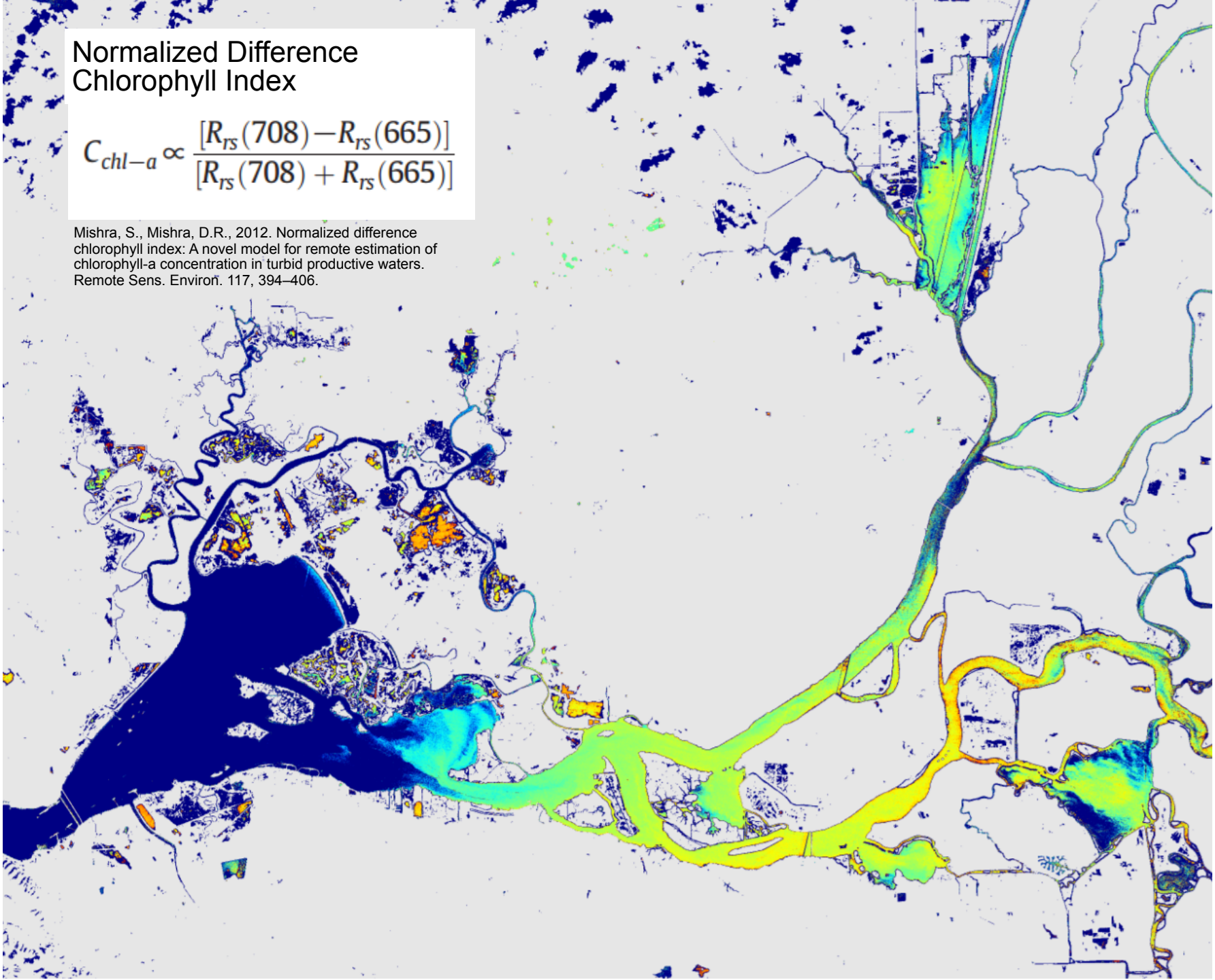


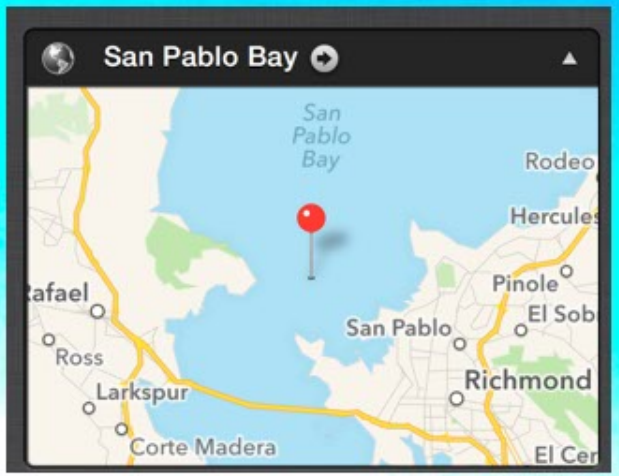

---- Provisional Data Subject to Revision ----



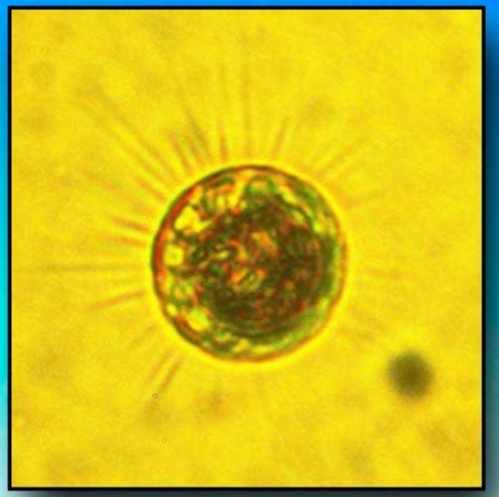
MOSES3B (mg $m^{-3}$)

0.10 1.00 10.00 100.00

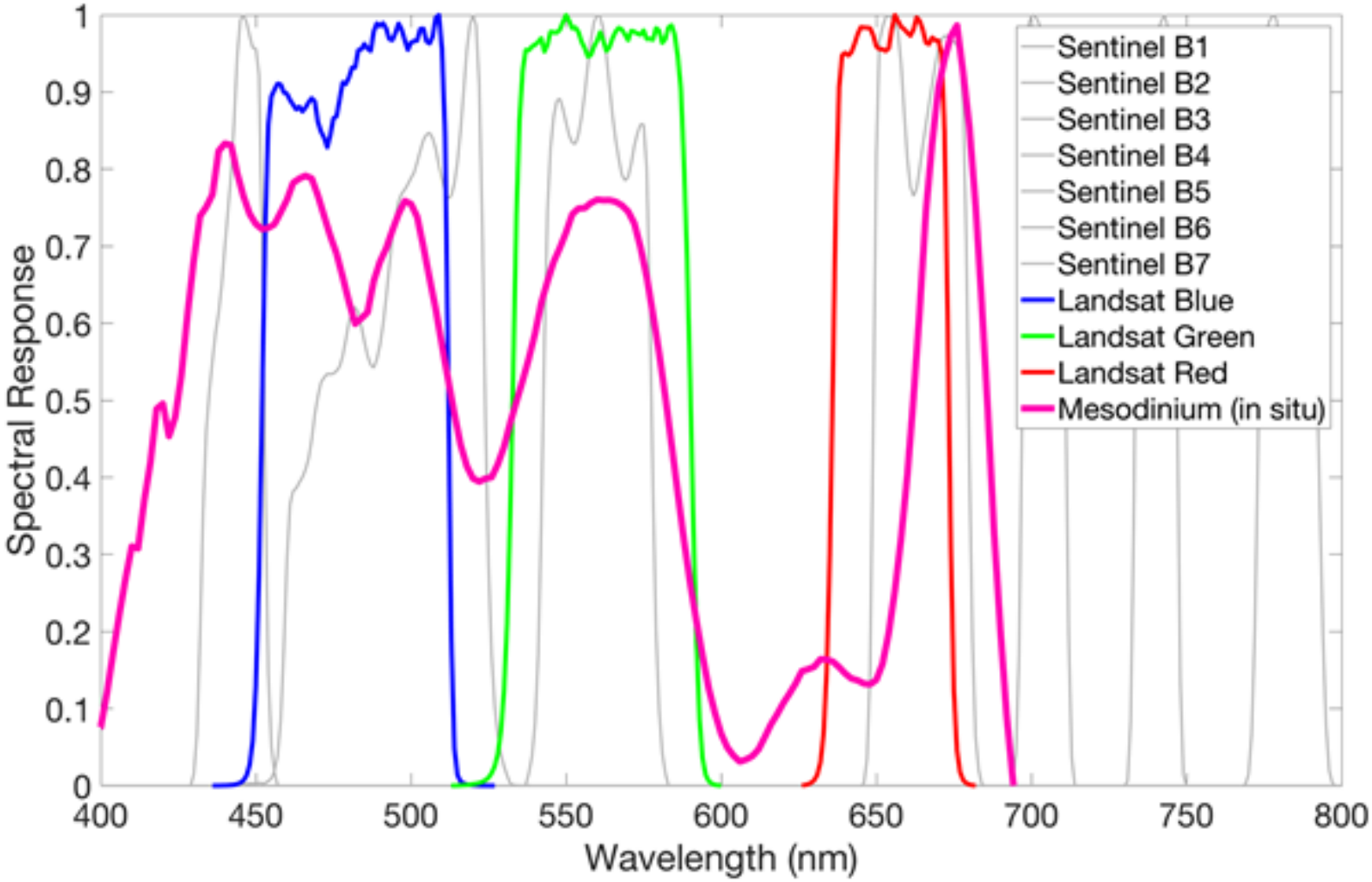

Normalized Difference Chlorophyll Index
$$C_{chl-a} \propto \frac{[R_{rs}(708) - R_{rs}(665)]}{[R_{rs}(708) + R_{rs}(665)]}$$
Mishra, S., Mishra, D.R., 2012. Normalized difference chlorophyll index: A novel model for remote estimation of chlorophyll-a concentration in turbid productive waters. Remote Sens. Environ. 117, 394–406.




Mesodinium Rubrum (red tide) observed from the R/V Questuary in the San Francisco Bay on 31 March 2016.



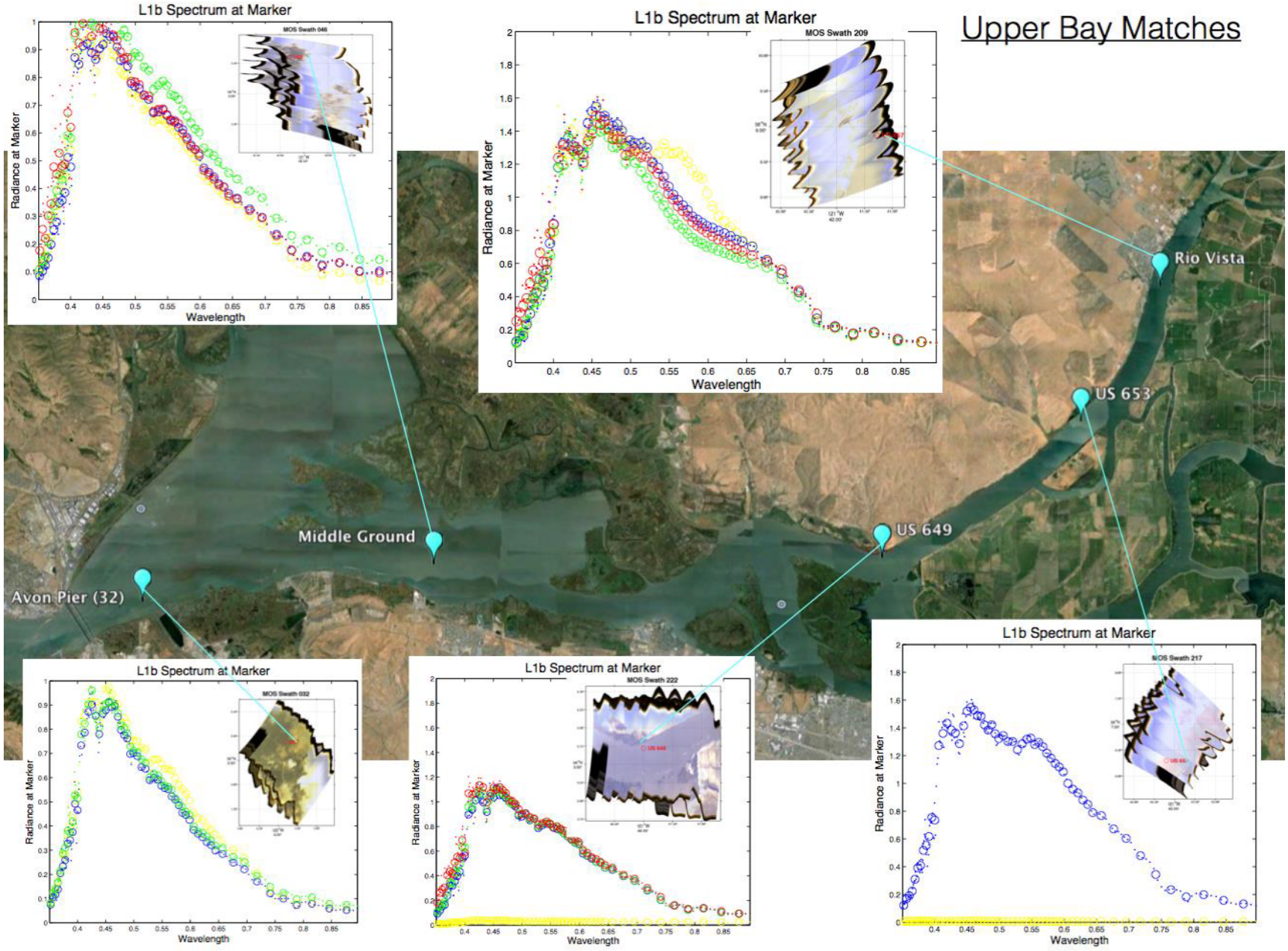
# Mesodinium Ruburm Spectra and Sensor Bands



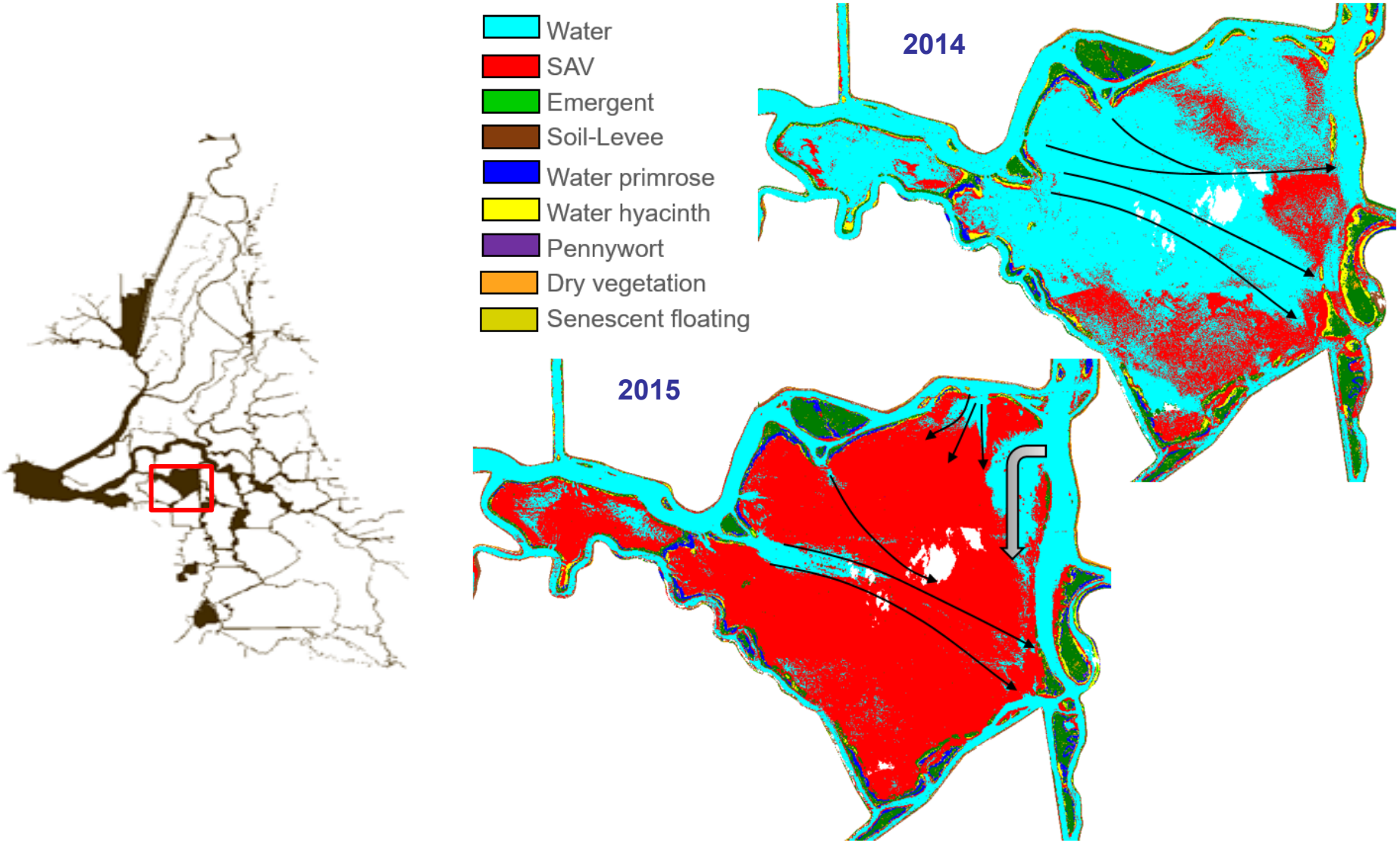
# Next Steps

# Use of NASA Airborne Sensors

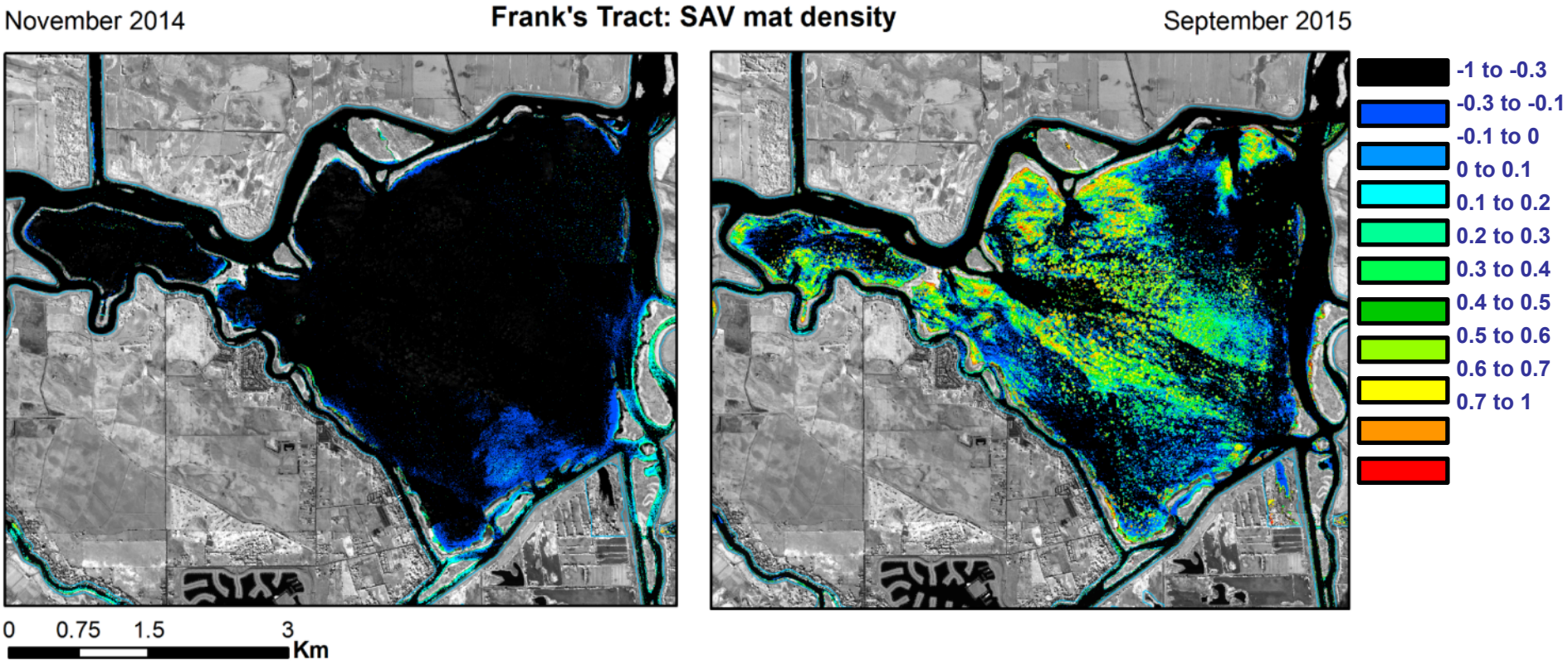
(PRISM, AVIRIS-NG, MOS)



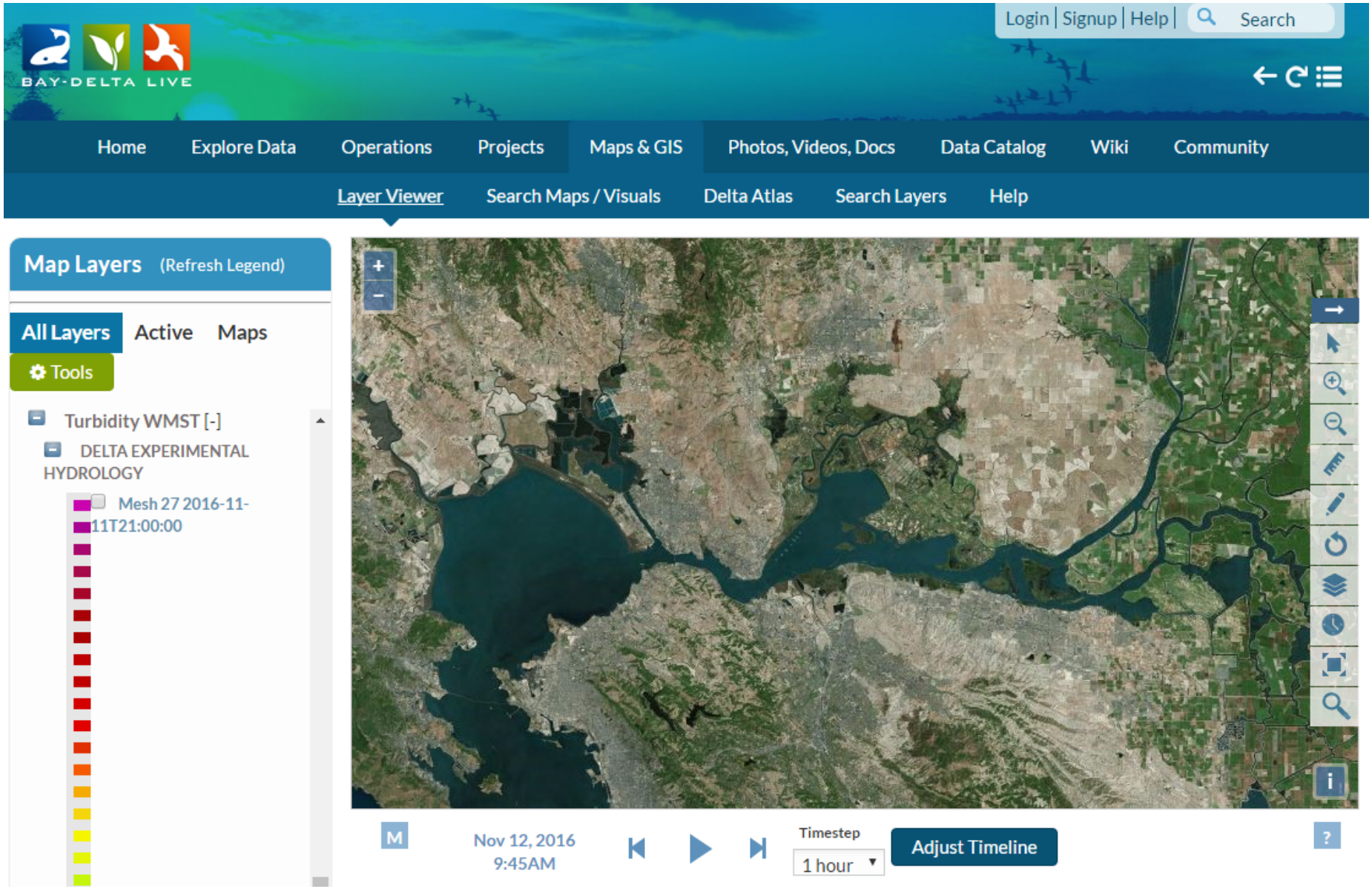
# Frank's Tract Vegetation classification



# SAV Mat density from Landsat



# Operational Products




NASA Proposal with **Christine Lee**, JPL

# Questions?