Overview of the RIO-SFE program and Remote Sensing with Landsat 8 and Sentinel 2

Curtiss O. Davis, Nicholas Tufillaro and Jasmine Nahorniak

College of Earth, Ocean and Atmospheric Sciences,
Oregon State University, Corvallis, OR, USA 97331
cdavis@coas.oregonstate.edu

Impacts of Population Growth on the San Francisco Bay and Delta Ecosystem (SFE)

The goal of this NASA Interdisciplinary Science project is to put in place an approach and modeling framework for the scientific basis of an ecosystem approach to the stewardship of the SFE including freshwater and marine resources within the SFE and adjacent ocean ecosystems. Our SFE project combines four components:

(1) Satellite observations (MERIS, HICO, Landsat, Sentinel 2 and in the future OLCI)

***(2)* *In situ* observations (nutrients, phytoplankton, suspended sediments, CDOM and optical properties)**

(3) CoSiNE bio-optical model of SFE integrated with the SCHISM hydrological model of SFE

(4) Coordination with Stakeholders

Three year effort to establish an integrated approach using remote sensing, in situ data and modeling to study SFE.

RIO-SFE Project

Remote/In situ Observing - San Francisco Bay and Estuary

Results and discussions with SFE Stakeholders: November 14, 2016 Sacramento, CA

Field Observations
(RTC, NRL and OSU)

CoSiNE ecological model
(Fei Chai, U. Maine)

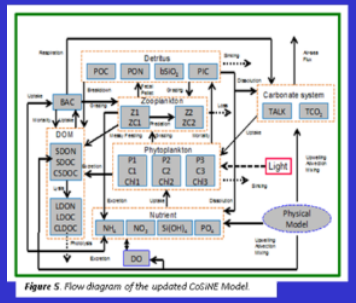
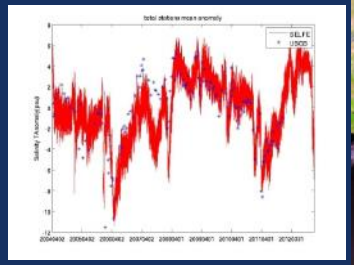


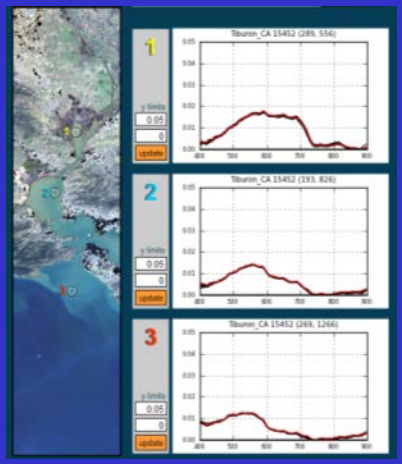
Figure 5. Flow diagram of the updated CoSiNE Model.

Results
merging data and models to understand SFE



SCHISM
Semi-implicit Cross-scale Hydroscience Integrated System Model
(Yi Chao, RSI)

Remote Sensing
(Curt Davis, OSU)



RIO-SFE Remote Sensing

MERIS

- 2002-2012, 10 year time series
- 300 m GSD, 16 ocean bands, high SNR

HICO

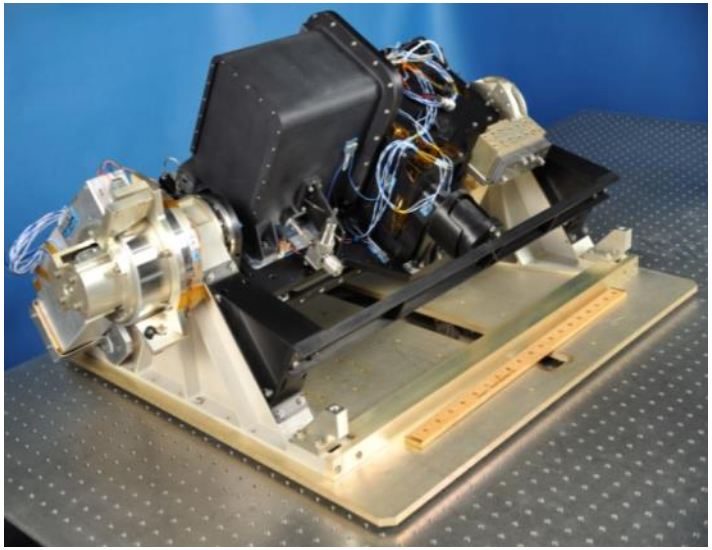
- Sept 2009 – Sept 2014
- 90 m GSD, high SNR
- hyperspectral (400 – 900 nm at 5.7 nm resolution)
- collects scenes on demand

Landsat-OLI

- 30 m GSD, 16 day revisit, land bands, moderate SNR, 15 m panchromatic band

Sentinel 2

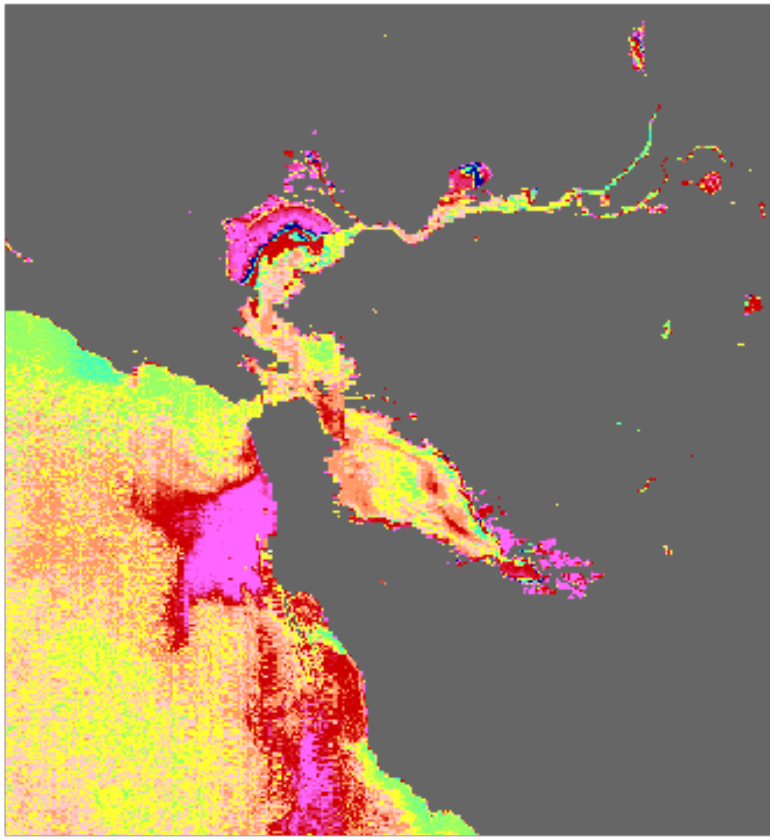
- 20 m GSD, additional bands for vegetation



MERIS FR image from 23 June 2011

- MERIS data are available over a 10 year period (2002 – 2012)
- MERIS provides 300 m GSD, 16 ocean bands, and high SNR

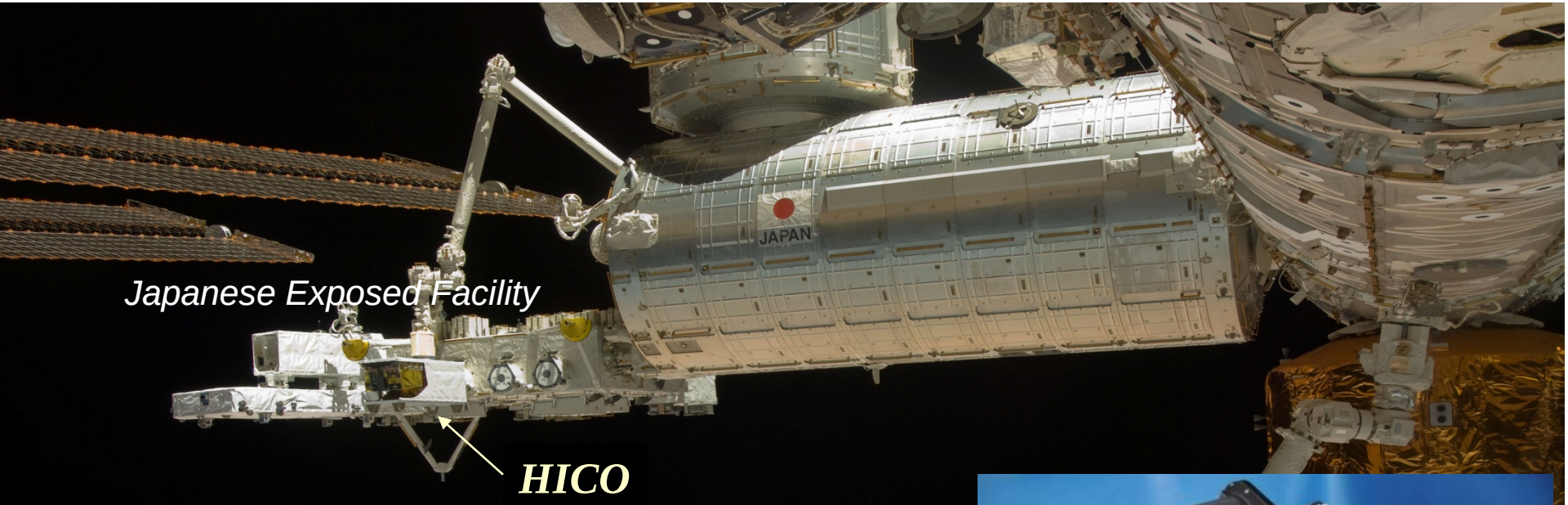
RGB image



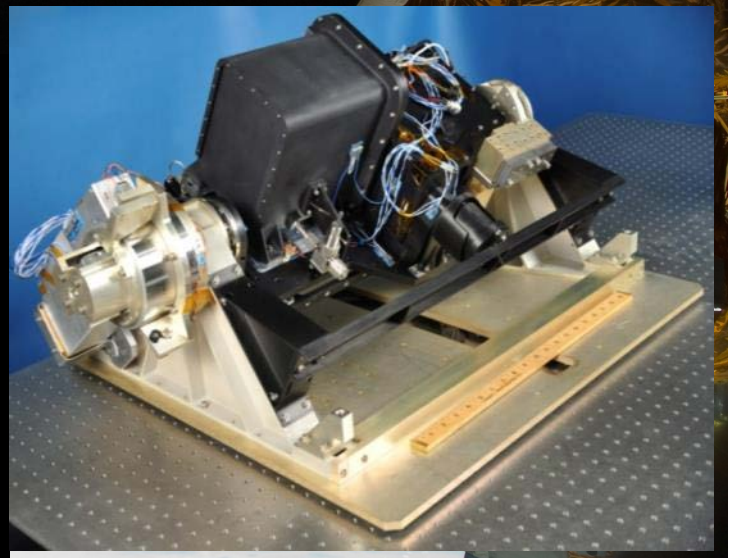
Algal-2 chlorophyll product showing values ranging from 2 (yellow) to 20 (pink) mg/m^3 .

HICO Summary: 5 Years of operation

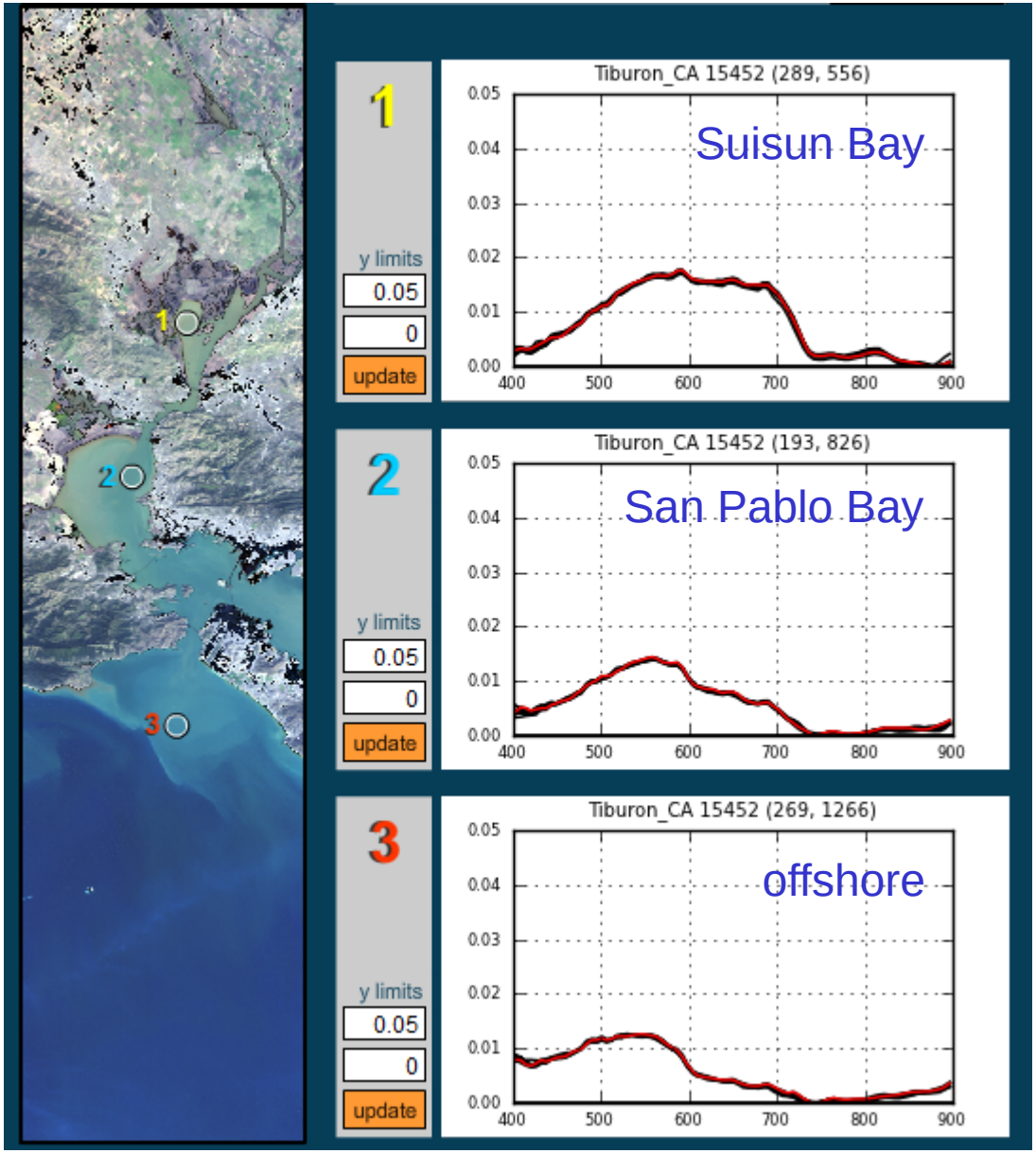
(http://hico.coas.oregonstate.edu)



- Built and launched in 28 months
- Operated on the ISS for 5 years
- Over 50 publications and 100 users
- Over 9000 scenes collected
- All Planned NASA Ocean color sensors are Hyperspectral



HICO image from February 19, 2014



Remote sensing reflectance spectra for:

(1) Suisun Bay (very high sediments),

(2) San Pablo Bay (high sediments), and

(3) offshore showing outflow from the Bay.

Having the full spectra allows separation of the sediment and chlorophyll signals and in some cases the identification of bloom species.

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.

Landsat 8 OLI Characteristics

Landsat 8 Operational Land Imager (OLI)	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
Launched February 11, 2013	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.

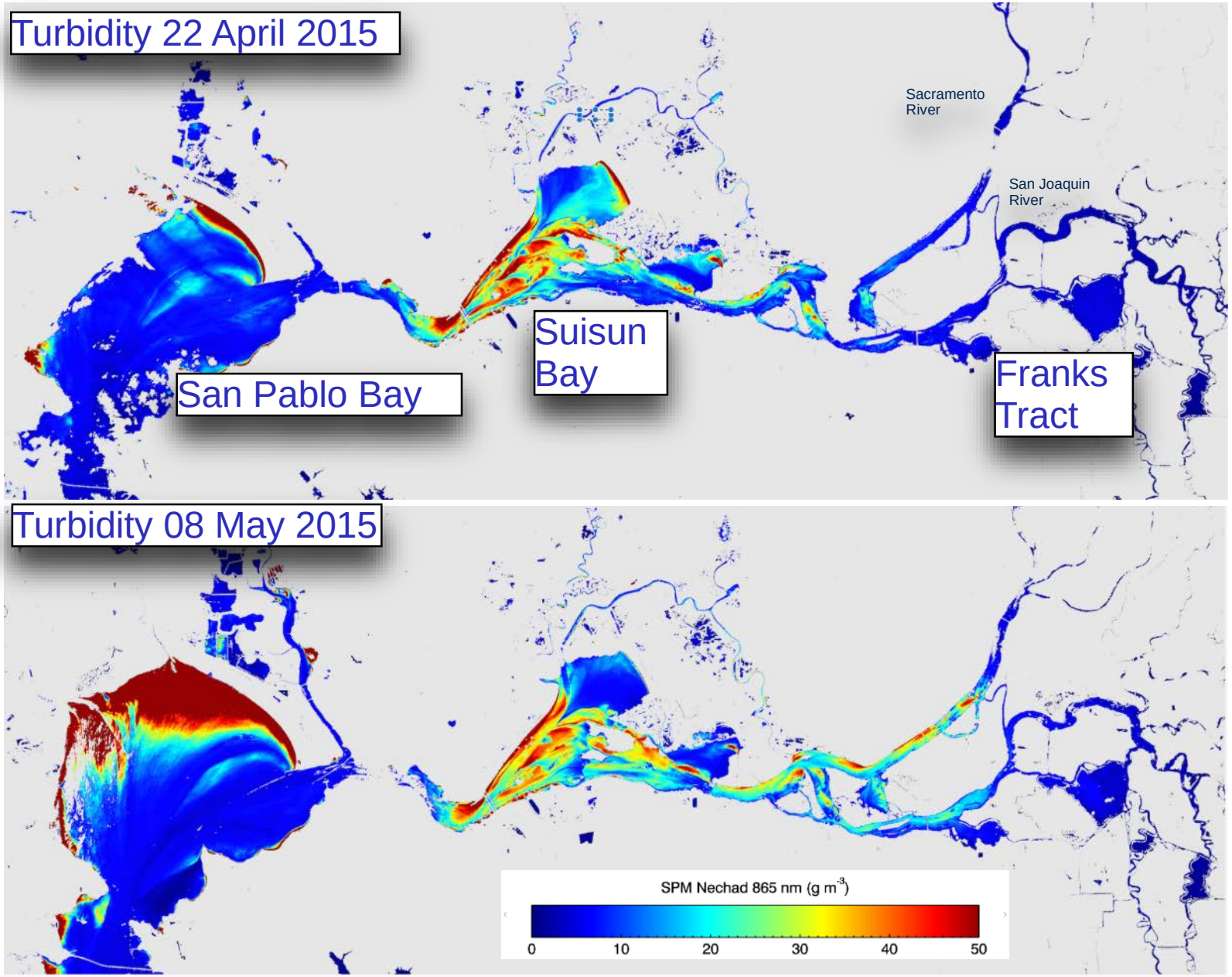
Landsat 8-OLI Processing Methods

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.

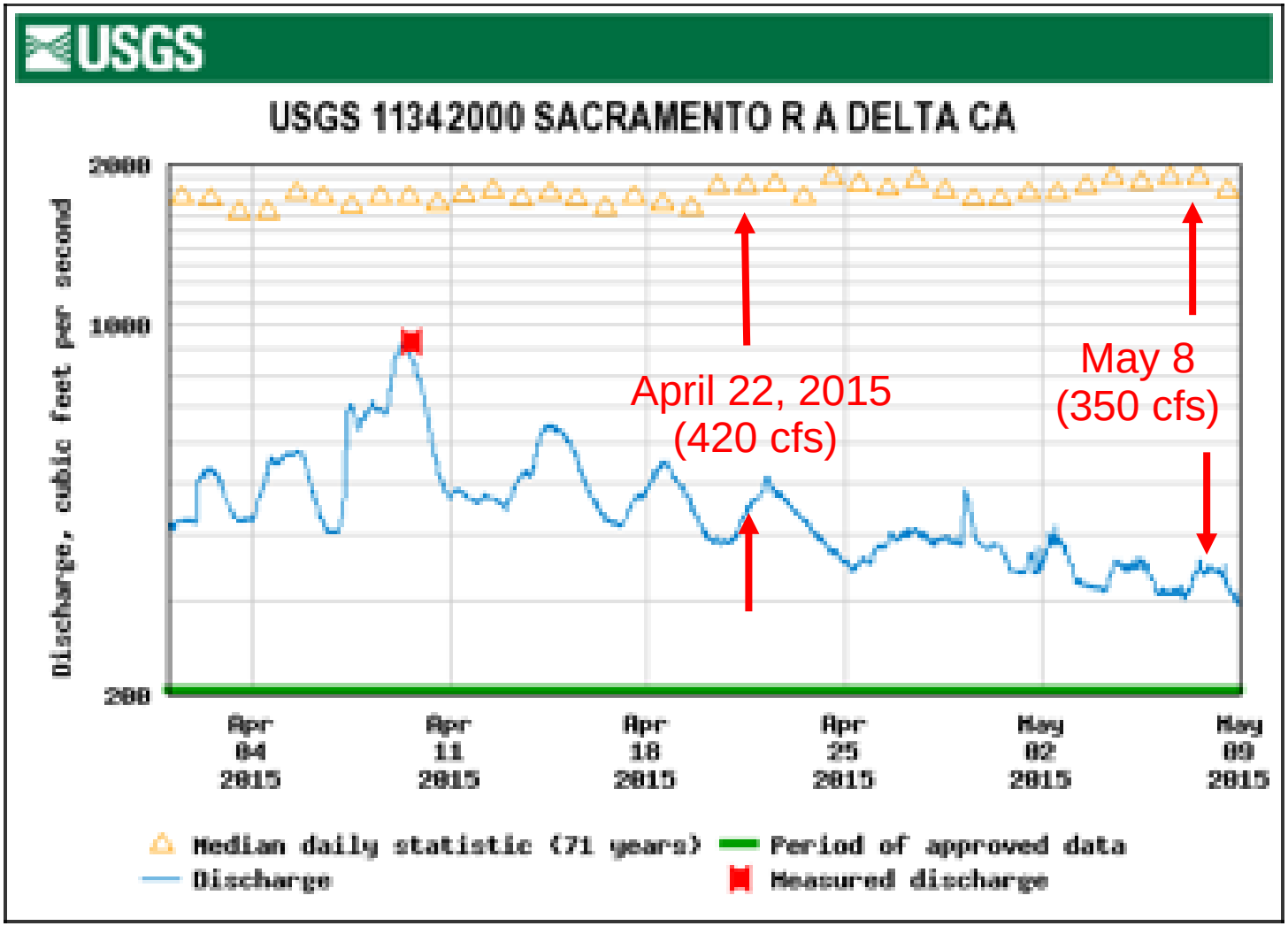
Total Suspended Sediment (TSS) maps (Nechad, Ruddick, and Park 2010) typically show an increase of turbidity in the lower Sacramento River and North San Pablo Bay. Product maps like these are used for the calibration and validation of the SFE model. The product maps are 'regionally tuned' using in situ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

Images are sharpened using the 15 m Panchromatic band.

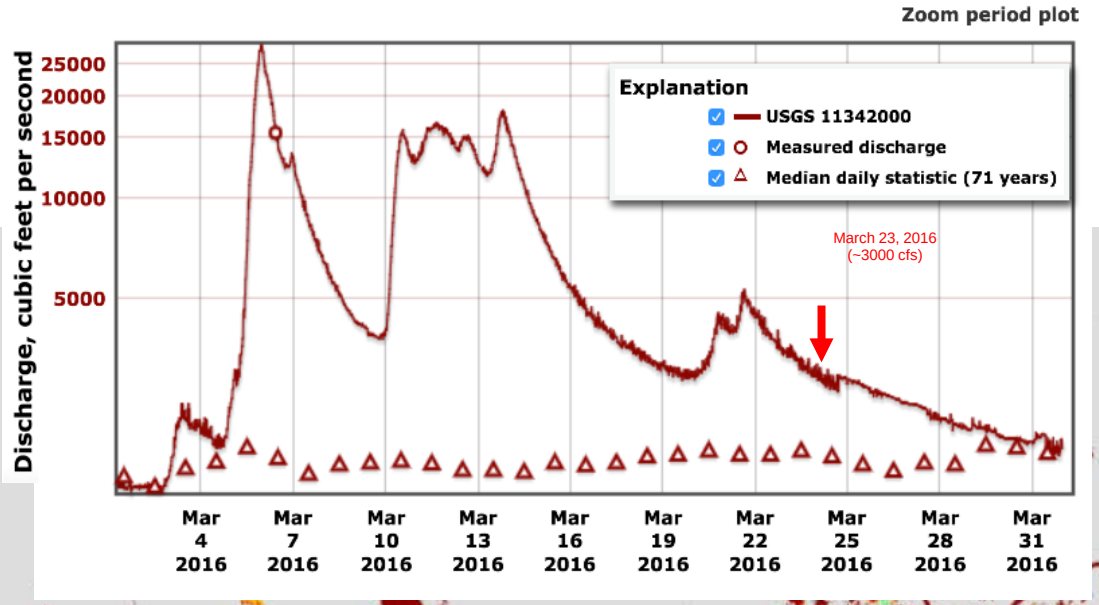
SPM Maps from L-8 OLI data



Sacramento River Flows during the Drought

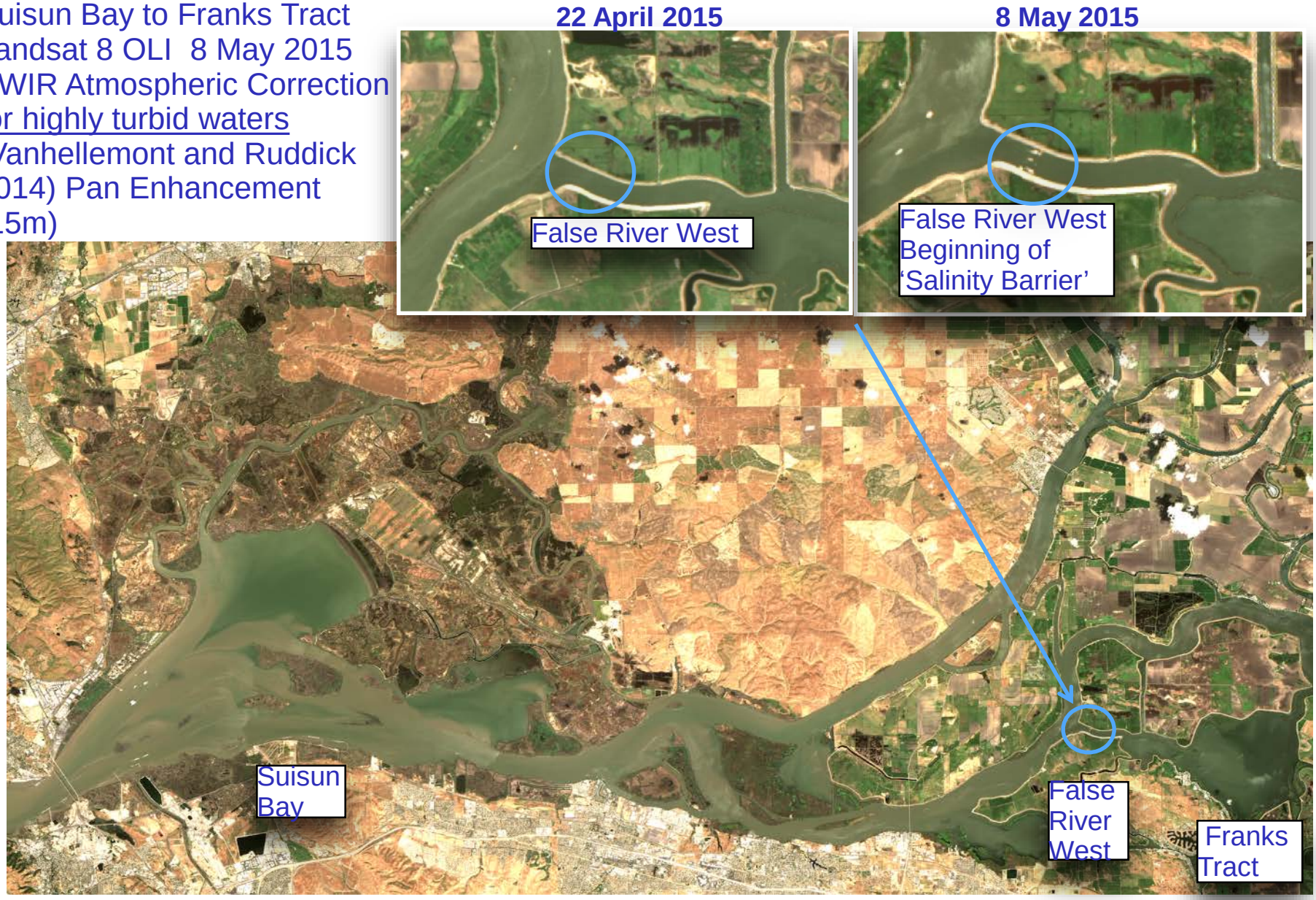


Landsat March 23, 2016 SPM



Following the Franks Tract Salinity Barrier

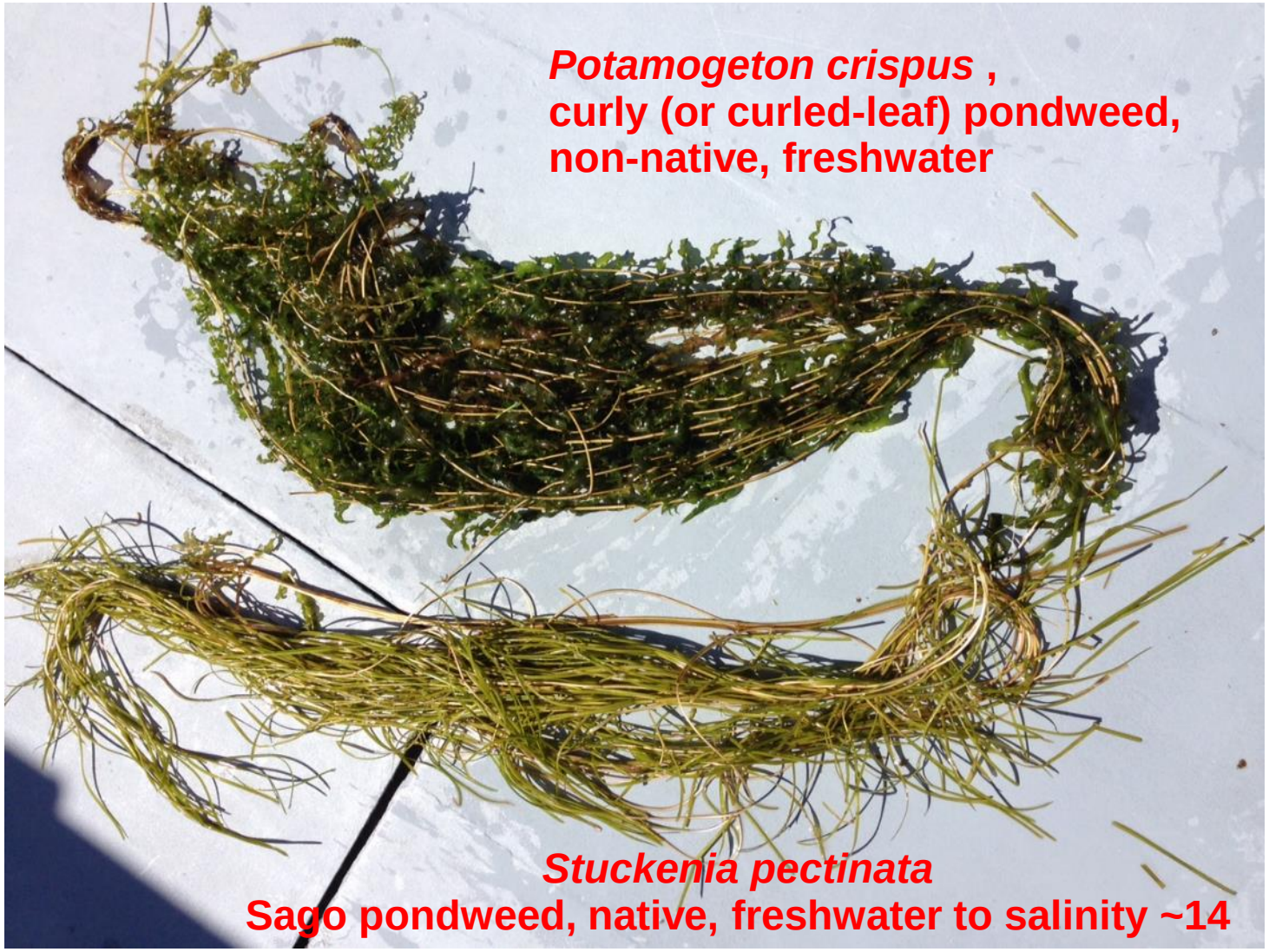
Suisun Bay to Franks Tract
Landsat 8 OLI 8 May 2015
SWIR Atmospheric Correction
for highly turbid waters
(Vanhellemont and Ruddick 2014) Pan Enhancement (15m)



LS-8 OLI Franks Tract Aug 12, 2015

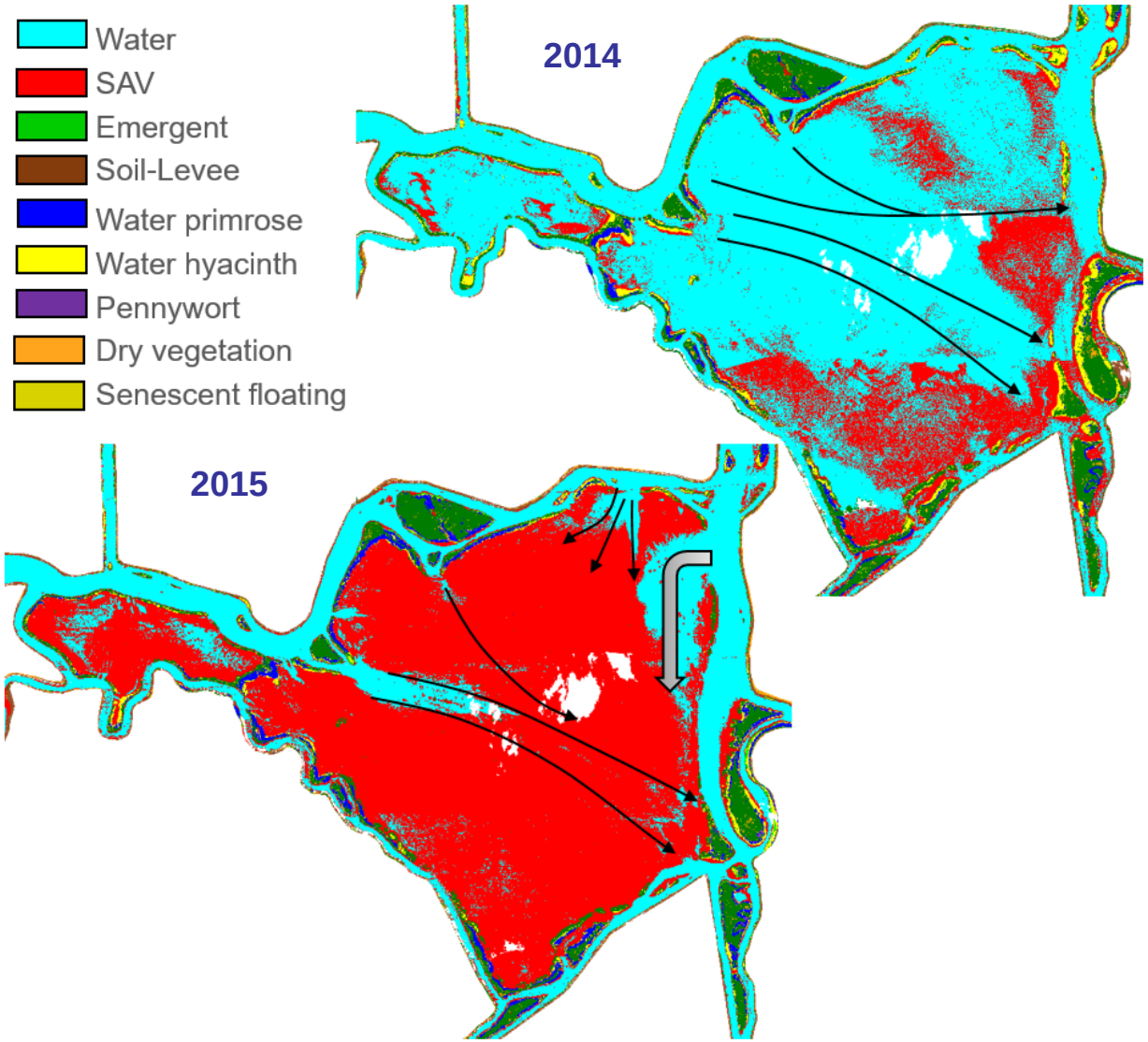
Macro Algae filling Franks Tract

Sept 4. 2015 Franks Tract ship samples

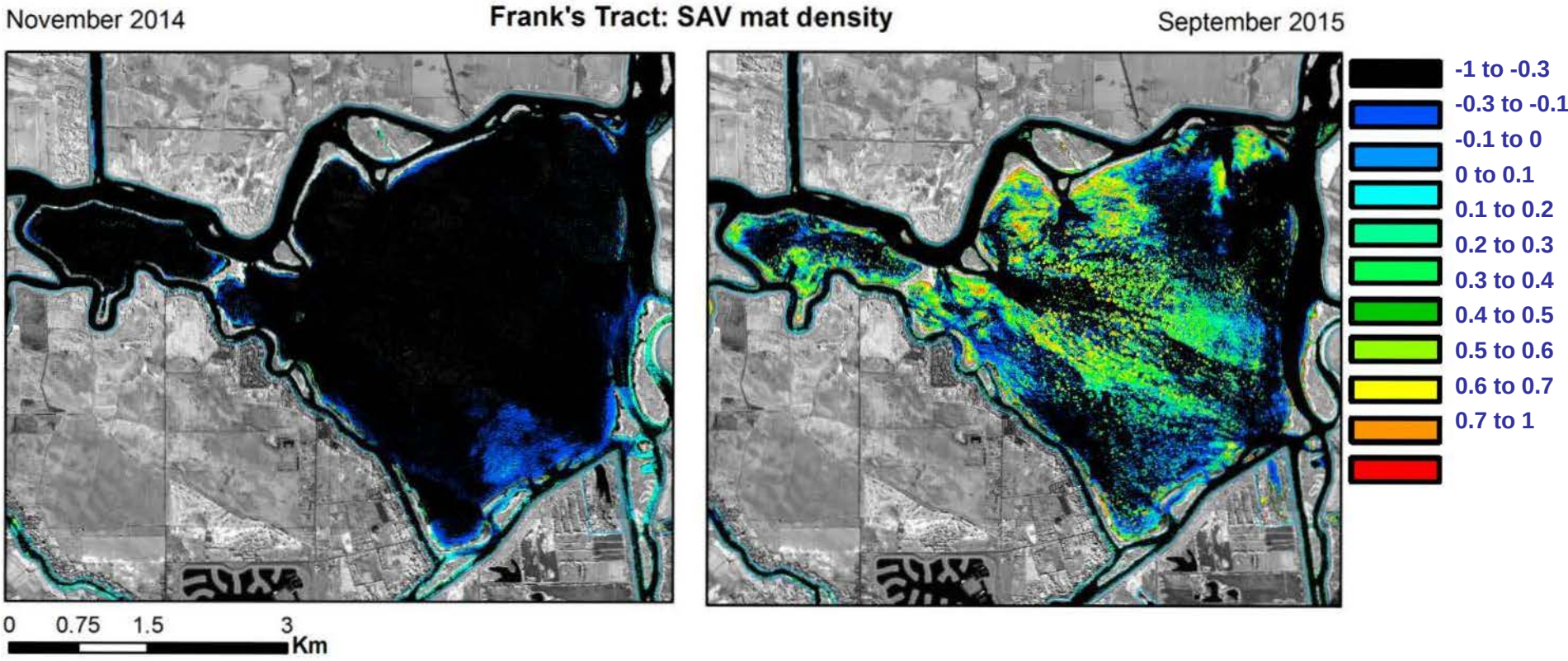


ASlaughter, photo

Frank's Tract Vegetation classification



SAV Mat density from Landsat



Sentinel 2 Bands — Even Better for Water

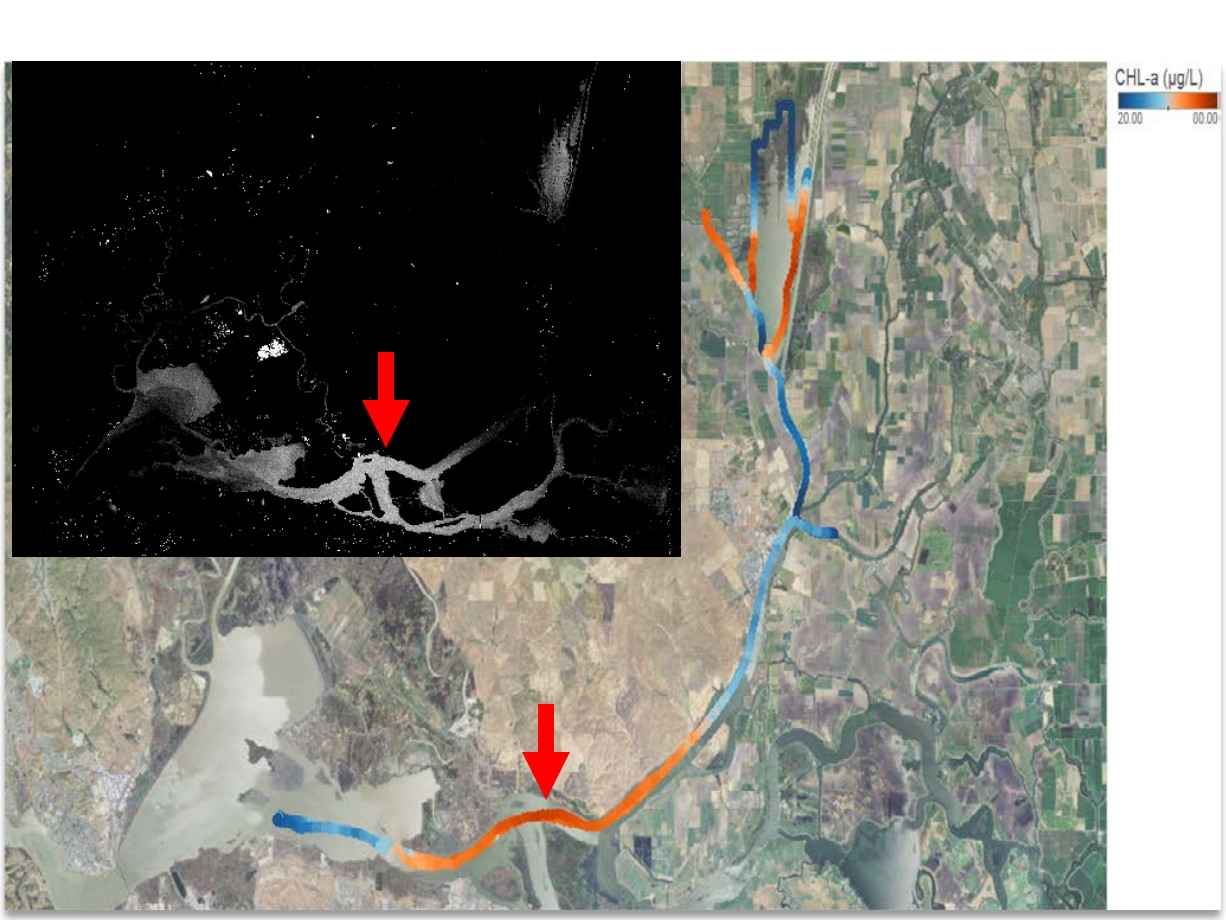
Sentinel-2 Bands	Central Wavelength (μm)	Resolution (m)
Band 1 - Coastal aerosol	0.443	60
Band 2 - Blue	0.490	10
Band 3 - Green	0.560	10
Band 4 - Red	0.665	10
Band 5 - Vegetation Red Edge	0.705	20
Band 6 - Vegetation Red Edge	0.740	20
Band 7 - Vegetation Red Edge	0.783	20
Band 8 - NIR	0.842	10
Band 8A - 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

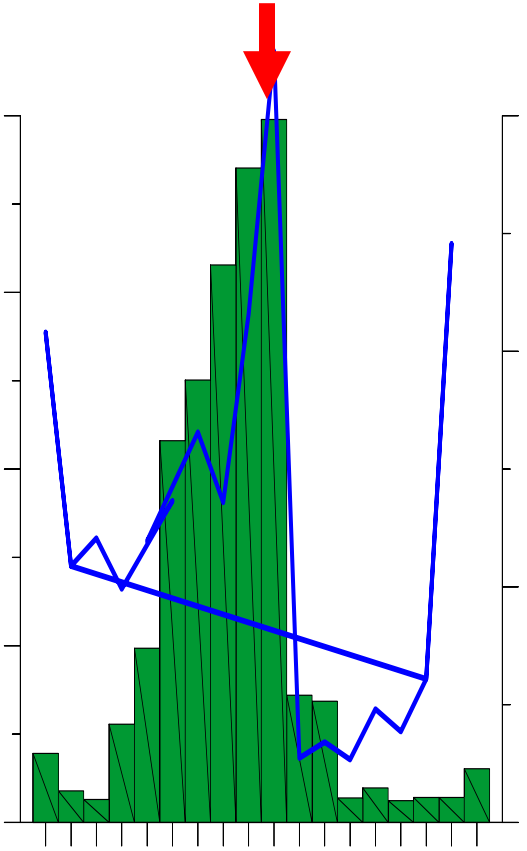
Spatial
10
Meters

Spectral -
Maximum
Chlorophyll
Index

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

May 2016 Bloom following March flood





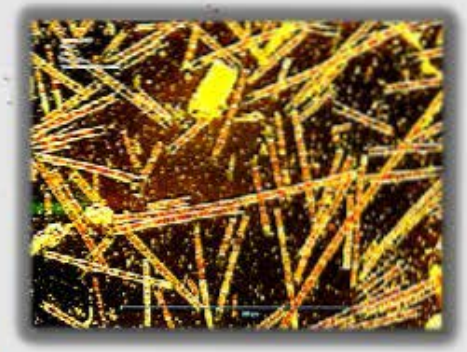
Left. Landsat image overlain with USGS (B. Bergamaschi) measured underway chlorophyll fluorescence from May 6, 2016. Inset May 15, 2016 Sentinel 2 image of the phytoplankton bloom (Gower et al. 2005 MCI algorithm). **Right.** SFE May 19 Cruise data for chlorophyll and f ratio (nitrate uptake rate/ (nitrate uptake rate + ammonium uptake rate) showing how the bloom forms when the phytoplankton are able to take up nitrate. Red arrows indicates the location of the peak bloom.

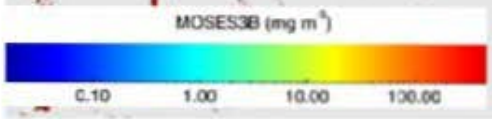
15 May Sentinel-2

Chlorophyll Estimate using MOSES3B

Red-edge algorithm (S2A only) to derive chlorophyll a concentration from the red band chlorophyll a absorption.

Moses, W.J., Gitelson, A.A., Berdnikov, S., Saprygin, V., Povazhnyi, V., 2012. Operational MERIS based NIR-red algorithms for estimating chlorophyll-a concentrations in coastal waters—The Azov Sea case study. Remote Sens. Environ. 121, 118–124.





Progress and Plans

- Complete processing and analysis of cruise data. Publications on time series of data and May 2016 bloom.
- Use MERIS 10 year time series to validate model results.
- Hyperspectral imaging very valuable to distinguish and quantify the diversity of coastal blooms (HICO examples)
- Land sensors can be very useful in the near coastal ocean (Landsat-8 OLI and Sentinel 2A) When Sentinel 2B is operational there will be 5 day repeat coverage. Continue routine monitoring of SFE.
- Collaborate on a publication on Franks Track
- All data available through NASA SEA-BASS data system

Coordinated team efforts are needed to deal with the complexity of SFE. High resolution remote sensing data essential to track blooms and other features.