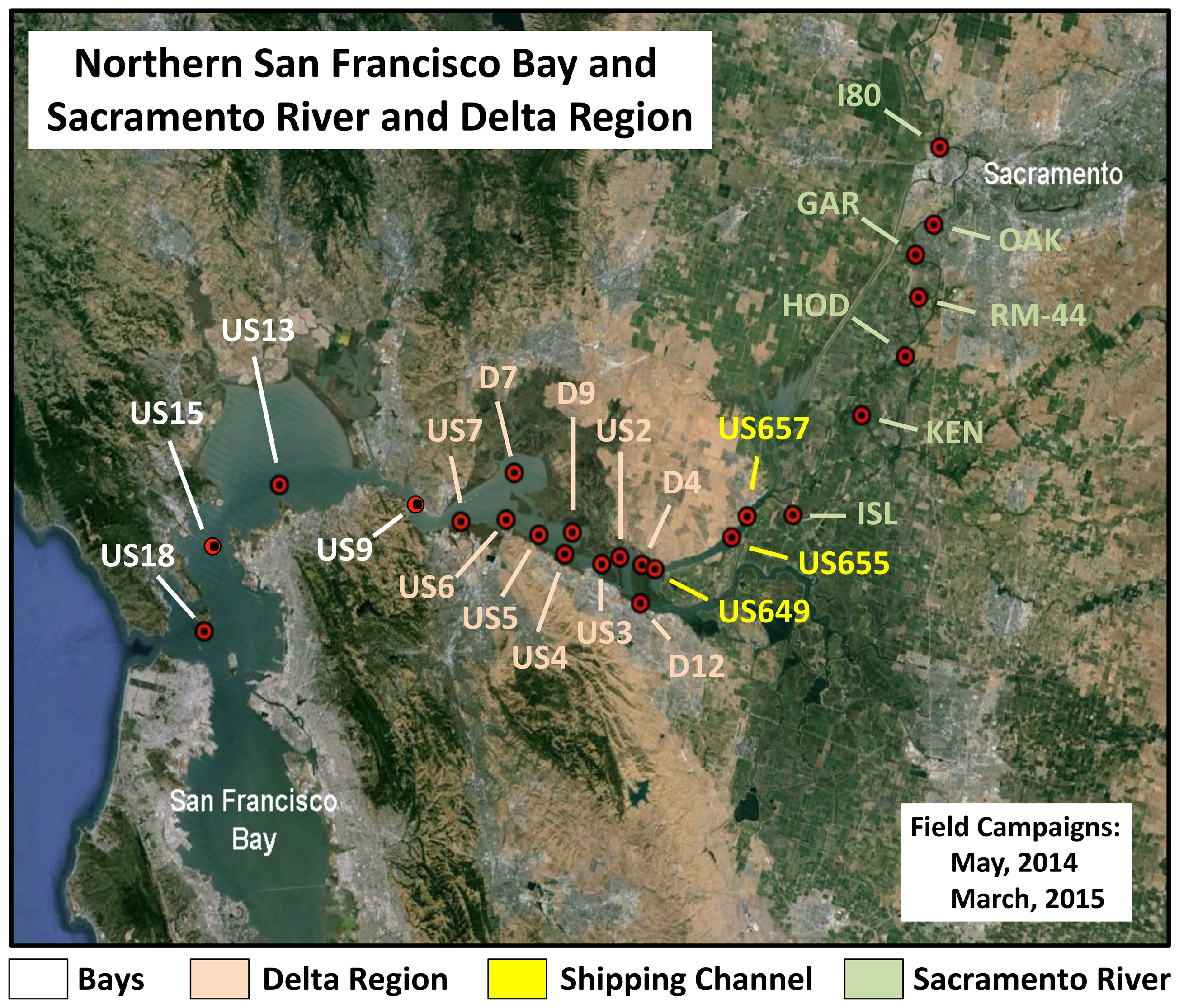
SFE-O: An Optical Model for the San Francisco Estuary

Steven G. Ackleson and **W. Joseph Rhea**, Naval Research Laboratory, Washington, D.C. (*steve.ackleson@nrl.navy.mil*)
Sarah Blaser, **Frances Wilkerson**, and **Richard Dugdale**, San Francisco State University
Curtis Davis and **Nick Tutillaro**, Oregon State University

Abstract:

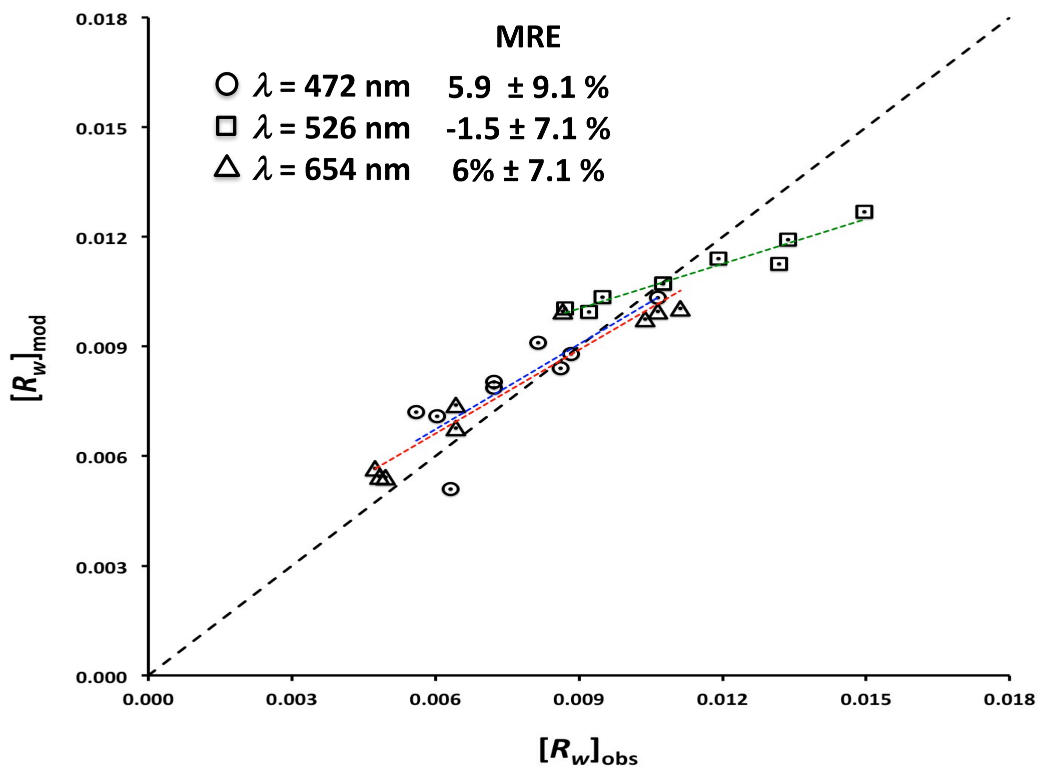
An optical model (SFE-O) for the northern portion of the San Francisco Estuary, including the lower reaches of the Sacramento River and Delta, is formulated based on three primary water constituents; suspended sediment concentration (C_{SPM} g m^{-3}), chlorophyll concentration (C_{chl} mg m^{-3}), and colored dissolved organic matter (*CDOM*). Field measurements of optical properties (*P*) and constituent concentration (*C*) are used to establish *P-C* relationships using data-directed mass-specific constants (*P'*) and stable spectral functions (*F*) such that *P=CP'F*. The optical model, combined with known pure water optical properties, defines the total absorption (*a*), light scatter (*b*), and fractional backscatter ($\tilde{b}_b$). Modeled values of *a*, *b*, and $\tilde{b}_b$ are used to drive a radiative transfer model, Hydrolight, to predict water reflectance (R_w) and the depth where light intensity decreases to 1% of surface photosynthetically active radiation ($z_{1\%PAR}$).



SFE-O Constituent Parameters

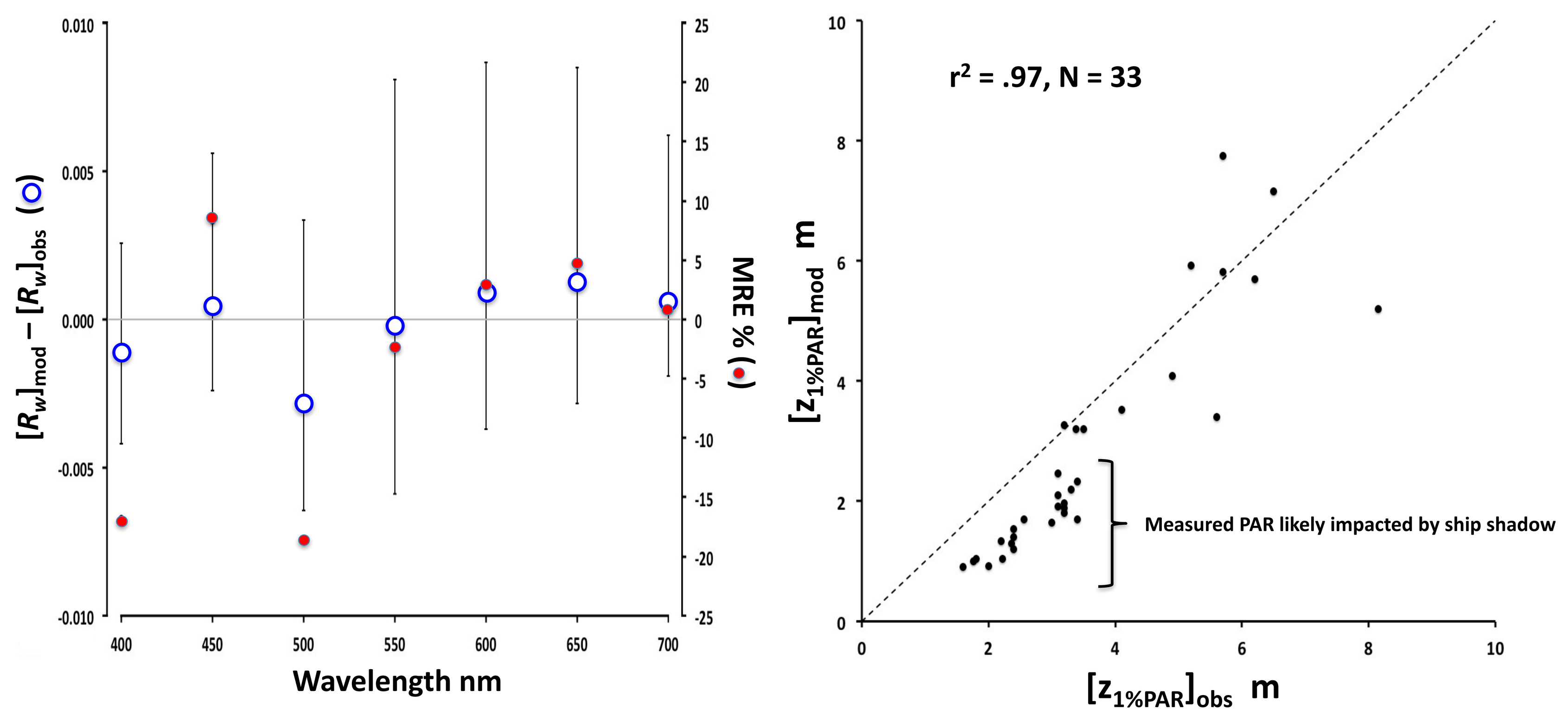
Constituent	*P* =	*C* *	*P'* *	$\mathcal{F}$
Phytoplankton	$a_{phy,\lambda}$	$C_{chl}\ mg\ m^{-3}$	$a'_{chl,675} = 0.013$ m^2 mg^{-1}	$\frac{a_{chl,\lambda}}{a_{chl,675}}$ (Stramski, 2002)
	$b_{phy,\lambda}$		$b'_{chl,675} = 0.125$ m^2 mg^{-1}	$\frac{b_{chl,\lambda}}{b_{chl,675}}$ (Stramski, 2002)
SPM	$a_{SPM,\lambda}$	$C_{SPM}\ g\ m^{-3}$	$a'_{SPM,489} = 0.049$ m^2 g^{-1}	$\sum_0^3 x_i[\lambda/\lambda_o]^i$ $\lambda_o = 489$ nm $x_0 = 19.741$ $x_1 = -43.174$ $x_2 = 32.864$ $x_3 = -8.428$
	$b_{SPM,\lambda}$		$b'_{SPM,652} = 0.417$ m^2 g^{-1}	$\left[\frac{\lambda}{\lambda_o}\right]^{-\eta}$ $\lambda_o = 652$ nm $\eta = 0.675$
CDOM	$a_{CDOM,\lambda}$	$a_{CDOM,489}/a^s_{CDOM,489}$ $0 \le C \le 1$	$a^{max}_{CDOM,489}$	$exp^{S_g(\lambda_o-\lambda)}$ $S_g = 0.0165$ nm^{-1} $\lambda_o = 489$ nm

Closure



- $[R_w]_{obs}$ measured with a hand-held ASD spectrometer; θ = 40°, ϕ = 135°, skys clear, water calm and optically deep.
- $[R_w]_{mod}$ modeled using Hydrolight; measured IOPs, β (*Fournier and Forand*) constrained by $\tilde{b}_b$, view angle θ = 40° and ϕ = 135°.
- MRE = $100 * \frac{1}{N}\sum_1^N \{([R_w]_{mod} - [R_w]_{obs})/[R_w]_{obs}\} = 3.5 \pm 4.5$ %

Validation



- $[R_w]_{obs}$ measured with ASD.
- $[R_w]_{mod}$ computed using Hydrolight and IOPs parameterized as water constituents.
- -19.9% (500 nm) ≤ MRE ≤ 8 % (450 nm)
- MRE larger in the blue due to greater uncertainty in the spectral shape functions for SPM and CDOM.

- PAR measured with Li-Cor 193 quantum meter.
- $[z_{1\%PAR}]_{obs}$ estimated from in situ measurements. $[z_{1\%PAR}]_{mod}$ computed using Hydrolight and IOPs parameterized as water constituents.
- MRE = -25.5 ± 9.1%
- Large MRE likely due to ship shadow effects on in situ observations of PAR.

Conclusions:

- The SFE-O model, driven by water constituent concentration and derived parameterizations, accurately describes water column reflectance and and the in-water light field.
- The environmental conditions underpinning the model represent extreme drought conditions and may be more representative of future conditions.
- The effects of inorganic and organic particles are combined into a single SPM parameterization. The validity of this approach is due to the regions history of inorganic sediment deposition, the processes controlling suspension of bottom sediments, and the co-location of wetlands, the dominant source of POC within the Delta.
- The shape of SPM absorption is described as a third-order polynomial rather than a CDOM-like power function and is similar in shape to published absorption spectra for organic detrital matter.
- SFE-O should prove helpful in the interpreting remotely sensed water color, understanding the near-term environmental conditions of the SFE, and predicting future environmental changes resulting from population and climate.

Sponsored by NASA Ocean Biology and Biogeochemistry Program • Presented at the 2016 Ocean Optics Meeting, Victoria, Canada