Modeling Trace Element Concentrations in the San Francisco Bay Estuary from Remote Measurement of Suspended Solids

Johanna Press1, Jennifer Broughton2, Raphael Kudela2

1 Department of Geology & Geophysics, Yale University, New Haven, CT; joanna.press@yale.edu
2 Ocean Sciences Department, UC Santa Cruz, Santa Cruz, CA

Introduction

High concentrations of trace element pollutants in the San Francisco Bay estuary necessitate consistent and thorough monitoring to mitigate adverse effects on biological systems and the contamination of water and food resources. Although the San Francisco Estuarine Institute’s Regional Monitoring Program collects annual in situ samples from fixed locations, models proposed by Benoit, Kudela, & Flegal (2010) enable calculation of the water column total concentration and the water column dissolved concentration for 12 trace elements in the San Francisco Bay from a more frequently sampled metric—suspended solids concentration (SSC). This study tests the application of these models using SSC calculated from remote sensing data, with the aim of validating a tool for continuous synoptic monitoring of trace elements in the San Francisco Bay.

Methods

Remote Sensing Data
Satellite imagery of the San Francisco Bay was chosen to align with the dates of annual Regional Monitoring Project (RMP) trace metal sampling. The Hyperspectral Imager for the Coastal Ocean (HICO) provides 86 bands of data with a spatial resolution of 90m and a bandwidth of 5.7nm. HICO imagery was radiometrically corrected to remote sensing reflectance values (rs), geo-corrected, and masked to contain only water pixels.

Calculating Suspended Solids Concentration
Semi-analytical and empirical algorithms for SSC were tested against USGS at-sites measurements. Methods tested included a semi-empirical algorithm using water-leaving reflectance to calculate SSC (Neshat, Buddik, & Park, 2010) as well as empirical location-specific models for SSC developed from ratios of Rs in various bands (Douaran, Fenselrud, & Castaing, 2002) and Rs of individual bands (Buddin et al., 2010; Miller & McKee, 2004). Models using single band proxies exhibited better fit than other types of algorithms. Models using each of the 86 HICO bands were tested, and the 634nm-band model exhibiting the best linear fit (R² = 0.794) was applied to the image to create a map of SSC.

Addressing Sunlight
When the sun reflects off the ocean surface at the satellite’s viewing angle, it can produce sunlight that erroneously raises remote sensing reflectance values and leads to false-positive SSC data. Areas affected by sunlight were excluded from further analysis.

Results

Model Results
Statistically significant (p ≤ 0.01) results for WCT were found for ten elements—As, Cd, Co, Cu, Fe, Hg, Mn, Ni, Pb, and Zn—with R² values between 0.50 and 0.80. R² was greater than or equal to that of the original models of Benoit, Kudela, & Flegal (2010) for seven of these elements. WCD was successfully modeled for six elements—As, Cd, Co, Cu, Ni, and Zn—with R² values between 0.40 and 0.85, exceeding that of the original models for each element.

Water Quality Implications
WCT values for As, Fe, and Pb were found to exceed EPA water quality criteria. Cu, Co, Mn, and Ni were present at more than 50% of the recommended concentration (U.S. EPA 2014). All elements were present at highest concentrations in the southern region of the Bay.

Literature Cited

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