The validity chlorophyll-a estimation by sun induced fluorescence in estuarine waters: An analysis of long-term (2003-2011) water quality data from Tampa Bay, Florida (USA)

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Satellite observation of phytoplankton concentration or chlorophyll-a is an important characteristic, critically integral to monitoring coastal water quality. However, the optical properties of estuarine and coastal waters are highly variable and complex and pose a great challenge for accurate analysis. Constituents such as suspended solids and dissolved organic matter and the overlapping and uncorrelated absorptions in the blue region of the spectrum renders the blue-green ratio algorithms for estimating chlorophyll-a inaccurate. Measurement of sun-induced chlorophyll fluorescence, on the other hand, which utilizes the near infrared portion of the electromagnetic spectrum, may provide a better estimate of phytoplankton concentrations. While modelling and laboratory studies have illustrated both the utility and limitations of satellite baseline algorithms based on the sun induced chlorophyll fluorescence signal, few have examined the empirical validity of these algorithms using a comprehensive long term in situ data set. In an unprecedented analysis of a long term (2003-2011) in situ monitoring data from Tampa Bay, Florida (USA), we assess the validity of the FLH product from the Moderate Resolution Imaging Spectrometer (MODIS) against chlorophyll-a and a suite of water quality parameters taken in a variety of conditions throughout a large optically complex estuarine system. A systematic analysis of sampling sites throughout the bay is undertaken to understand how the relationship between FLH and in situ chlorophyll-a responds to varying conditions within the estuary including water depth, distance from shore and structures and eight water quality parameters. From the 39 station for which data was derived, 22 stations showed significant correlations when the FLH product was matched with in situ chlorophyll-α data. The correlations (r^2) for indvudual stations within Tampa Bay ranged between 0.67 ($n=28$, $p<0.01$) and -0.457 ($n=12$, $p=.016$), indicating that for some areas within the Bay, FLH can be a good predictor of chlorophyll-α concentration and hence a useful tool for the analysis of water quality. Overall, the results show a 106% increase in the validity of chlorophyll-a concentration estimates using FLH over the standard the blue-green OC3M algorithm. This analysis also illustrates that the correlations between FLH and in situ chlorophyll-a measurements increases with increasing water depth and distance of the monitoring sites from both the shore and structures. However, due to confounding factors related to the complexity of the estuarine system, a linear improvement in the FLH to chlorophyll-a relationship was not clearly noted with increasing depth and distance from shore alone. Correlations of FLH with turbidity, nutrients (total nitrogen and total phosphorous) biological oxygen demand, salinity, sea surface temperature correlated positively with FLH concentrations, while dissolved oxygen and pH showed negative correlations. Principle component analyses are employed to further describe the relationships between the multivariate water quality parameters and the FLH product. The majority of sites with higher and very significant correlations ($p<0.01$) also showed high correlation values for nutrients, turbidity and biological oxygen demand. These sites were on average in greater than seven meters of water and over five kilometers from shore. A thorough understanding of the

relationship between the MODIS FLH product and in situ water quality parameters will enhance our understanding of the accuracy MODIS's global FLH algorithm and assist in optimizing its calibration for use in monitoring the quality of estuarine and coastal waters worldwide.