Estuarine, Coastal and Shelf Science 89 (2010) 62–72

Contents lists available at ScienceDirect

Estuarine, Coastal and Shelf Science

journal homepage: www.elsevier.com/locate/ecss

Short-term variability of suspended sediment and phytoplankton in Tampa Bay, Florida: Observations from a coastal oceanographic tower and ocean color satellites

Zhiqiang Chen [1,*], Chuanmin Hu, Frank E. Muller-Karger, Mark E. Luther

College of Marine Science, 140 Seventh Avenue South, Saint Petersburg, Florida, 33701, USA

ARTICLE INFO

Article history:
Received 16 February 2009
Accepted 25 May 2010
Available online 2 June 2010

Keywords:
short-term variability
phytoplankton
sediment
remote sensing
bio-optic sensors
U.S.A.
Florida
Tampa Bay

ABSTRACT

We examined short-term phytoplankton and sediment dynamics in Tampa Bay with data collected between 8 December 2004 and 17 January 2005 from optical, oceanographic, and meteorological sensors mounted on a coastal oceanographic tower and from satellite remote sensing. Baseline phytoplankton (chlorophyll-*a*, Chl) and sediment concentrations (particle backscattering coefficient at 532 nm, bbp (532)) were of the order of 3.7 mg m^{-3} and 0.07 m^{-1}, respectively, during the study period. Both showed large fluctuations dominated by semidiurnal and diurnal frequencies associated with tidal forcing. Three strong wind events (hourly averaged wind speed >8.0 m s^{-1}) generated critical bottom shear stress of >0.2 Pa and suspended bottom sediments that were clearly observed in concurrent MODIS satellite imagery. In addition, strong tidal current or swells could also suspend sediments in the lower Bay. Sediments remained suspended in the water column for 2–3 days after the wind events. Moderate Chl increases were observed after sediment resuspension with a lag time of ˜1–2 days, probably due to release of bottom nutrients and optimal light conditions associated with sediment resuspension and settling. Two large increases in Chl with one Chl > 12.0 mg m^{-3} over ˜2 days, were observed at neap tides. For the study site and period, because of the high temporal variability in phytoplankton and sediment concentrations, a monthly snapshot can be different by −50% to 200% from the monthly "mean" chlorophyll and sediment conditions. The combination of high-frequency observations from automated sensors and synoptic satellite imagery, when available, is an excellent complement to limited field surveys to study and monitor water quality parameters in estuarine environments.

1. Introduction

Estuaries are highly dynamic environments where rivers, winds, and tides interact to determine physical, chemical, and biological variability. These driving factors lead to a wide range of temporal scales of phytoplankton and sediment variability in estuaries (Cloern et al., 1989; Cloern, 1991; Harding, 1994; Li and Smayda, 2001; Roegner et al., 2002). Superimposed on "periodic" variations due to diel variability, tides, and seasonal cycles are aperiodic or episodic (short-term) meteorological events. Wind pulses modify estuarine circulations and water levels and generate waves and currents that suspend sediments (e.g., Schoellhamer, 1995) and mix nutrients and benthic algae into overlying waters (Lawrence et al., 2004; Yeager et al., 2005).

Short-term variability in sediment has been well documented using optical and/or acoustic sensors (Schoellhamer, 1995; Jing and Ridd, 1996; Li and Amos, 2001). However, one of the main obstacles to studying short-term variability of phytoplankton in estuaries has been lack of reliable and cost-effective means for high-frequency sampling (e.g., Roegner et al., 2002). As a result, there are very few attempts to examine the relationship between sediment and phytoplankton dynamics, while this interaction is known to be critical in some estuaries (May et al., 2003; Desmit et al., 2005).

Tampa Bay is the largest estuary in Florida with a surface area of ˜1000 km^2. The average depth of the Bay is ˜4.0 m, with a dredged channel (>10 m) extending from the mouth of the bay to the upper bay. Tampa Bay is often divided into 4 segments based on geomorphologic differences and salinity regimes (Lewis and Whitman, 1985), namely Old Tampa Bay (OTB), Hillsborough Bay (HB), Middle Tampa Bay (MTB) and Lower Tampa Bay (LTB) (Fig. 1). An effort to control severe eutrophication problems in the 20th century led to a systematic water quality monitoring program across the Bay (Boler et al., 1991). The monitoring program conducts field surveys

* Corresponding author.
E-mail address: zchen@marine.usf.edu (Z. Chen).
[1] Present address: South Florida Water Management District, 3301 Gun Club Road, West Palm Beach, FL 33406, U.S.A.

0272-7714/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.ecss.2010.05.014

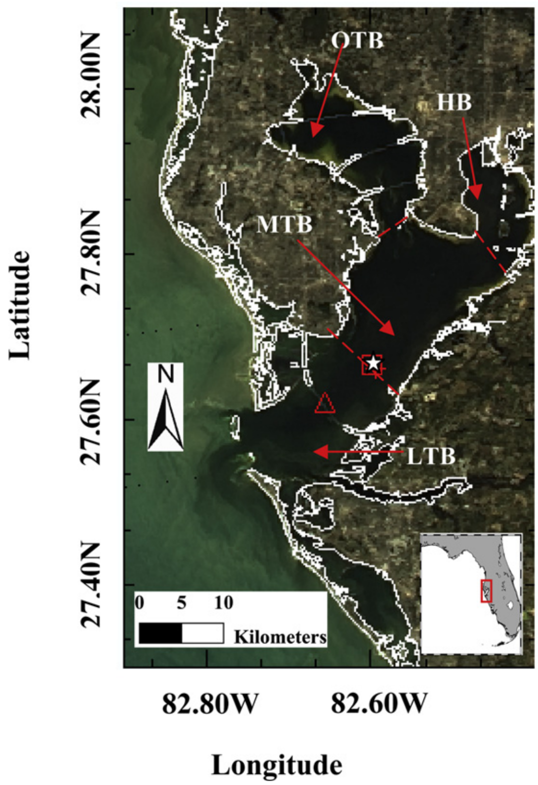

Fig. 1. Satellite image of Tampa Bay collected on 20 December 2004 with Moderate Resolution Imaging Spectroradiometer (MODIS/Aqua). Four bay segments are outlined with dashed lines: Old Tampa Bay (OTB), Hillsborough Bay (HB), Middle Tampa Bay (MTB), and Lower Tampa Bay (LTB). Data collection locations are annotated: Tower station (star) at Manatee Channel collected meteorological, oceanographic, and optical data; SunshineSkyway Bridge station (triangle) collected Acoustic Doppler Current Profile (ADCP) current data. The EPCHCTampa Bay water quality monitoring station (square) is the site of a 7-year (1997–2003) monthly time series of chlorophyll (mg m^{-3}) and turbidity (NTU) data. The inset showing the location of Tampa Bay in the State of Florida.

only once per month, which is customary for water quality surveys in other estuaries. These monthly data have been widely used to characterize long-term changes in water quality (Janicki et al., 2001; Schmidt and Luther, 2002). However, there has been little information available on short-term variability of phytoplankton and sediment concentrations in the Bay.

In this paper we examine the short-term variability of phytoplankton and sediment in Tampa Bay using data collected from automated sensors mounted on a coastal oceanographic tower and from satellites. Our objectives were: (1) to characterize short-term patterns of variations in phytoplankton and sediment in Tampa Bay; (2) to understand underlying mechanisms responsible for the observed variability; and (3) to discuss implications of short-term variability on water quality assessments for Tampa Bay and other estuaries. We found that high-frequency in situ data and synoptic satellite remotely sensed data are important complements, if available, to field surveys that are limited in scope due to personnel and other costs.

2. Materials and methods

2.1. In situ automated sensors

An array of automated bio-optical, hydrographic and meteorological sensors was deployed at a coastal oceanographic tower station in Tampa Bay, Florida, to measure physical conditions and phytoplankton and sediment concentrations from 8 December 2004 to 17 January 2005. The station was located near the middle of the Bay (27. 661°N, 82.583°W, Fig. 1) at a bottom depth of 4.6 m.

Two types of optical sensors were deployed. One was the WETLabs™ ECO-BBSB sensor to measure particle backscattering coefficient at 532 nm (bbp(532), which is a proxy for suspended sediment concentration (e.g., D'Sa et al., 2007). The other was the WETLabs™ ECO-FLNTUSB sensor to measure in vivo chlorophyll-*a* fluorescence near 683 nm, used as a proxy for chlorophyll-*a* concentration (Chl). Both sensors had an internal battery for continuous data logging. To determine possible vertical differences in phytoplankton and sediment between the surface and bottom layers, one set of sensors (i.e., backscattering sensor and fluorometer) was installed at 1 m depth below the surface with sensors facing down to minimize possible interference from sunlight. The other was installed at 1.5 m above the bottom with sensors facing up to minimize possible interference from bottom reflectance. Sampling frequency was set to 1 h^{-1}. The recorded raw data (voltage) were processed with the WETLabs™ ECOView software and converted to bbp(532) (m^{-1}) and chlorophyll-*a* concentration (Chl, mg m^{-3}) using calibration coefficients provided by the manufacturer. Those "default" Chl data were further calibrated using chlorophyll-*a* concentrations determined from discrete bottle samples collected concurrently near the tower station and analyzed with the standard fluorometric method (Strickland and Parsons, 1972).

Although Chl derived from in vivo fluorescence may not be an accurate proxy of biomass for every case due to environmental influences on the physiology and taxonomic status of the phytoplankton assemblages, in practice numerous publications show excellent correlation between the two for various environments including estuaries (Li and Smayda, 2001; Roegner et al., 2002). We have shown that in Tampa Bay there is a good correlation between in vivo fluorescence and Chl for Chl between 10 and 30 mg m^{-3} (Hu et al., 2004). Newer results from a cruise survey in April 2008 further confirmed this finding for low Chl (1.3–2.5 mg m^{-3}, see supplemental materials). However, a close examination of the in vivo fluorescence found that under high solar irradiation around noon, fluorescence was affected by non-photochemical quenching effects (see results below). We therefore used the method of Morrison (2003, equation 18 and derived parameters) to model the fluorescence efficiency (or quantum yield of fluorescence) as a function of photosynthetically active radiation (PAR). A PAR threshold was determined by visual comparison of Chl and PAR time series, with the latter corrected for light attenuation between surface and 1 m using a PAR attenuation coefficient of 0.8 m^{-1} (our unpublished data). The estimated PAR threshold was ~100 μmol photons m^{-2} s^{-1}, close to those reported elsewhere (Marra, 1997; Morrison, 2003). Then, we used three non-photochemical quenching values, namely 0.1, 0.5 and 0.9, to represent minimum, medium, and maximum non-photochemical effects, respectively, to obtain the "true" Chl values.

Salinity, temperature, and water pressure were measured with a Sea Gauge (Sea Bird Electronics) sensor deployed about 2.2 m above the sea floor. Wave height and period were computed using the standard Sea bird Electronics wave and tide recorder software, which uses linear wave theory and the standard surface gravity wave dispersion relation. Several above-water sensors measured wind speed, barometric pressure, and solar PAR. Water level was estimated from water pressure and barometric pressure Detailed descriptions of sampling of these data were given by Sopkin et al. (2007). The meteorological and oceanographic data were normally sampled at higher frequency (once per 6 or 15 min) and binned into hourly averages to facilitate comparisons with the optical data.