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Characterization of turbidity in Florida's Lake Okeechobee and Caloosahatchee and St. Lucie Estuaries using MODIS-Aqua measurements

Menghua Wang [a,*], *Carl J. Nim* [a,1], *SeungHyun Son* [a,b], *Wei Shi* [a,b]

[a] *NOAA National Environmental Satellite, Data, and Information Service, Center for Satellite Applications and Research, E/RA3, 5830 University Research Ct., College Park, MD 20740, USA*

[b] *CIRA at Colorado State University, Fort Collins, CO, USA*

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ABSTRACT

This paper describes the use of ocean color remote sensing data from the Moderate Resolution Imaging Spectroradiometer (MODIS) onboard the Aqua satellite to characterize turbidity in Lake Okeechobee and its primary drainage basins, the Caloosahatchee and St. Lucie estuaries from 2002 to 2010. Drainage modification and agricultural development in southern Florida transport sediments and nutrients from watershed agricultural areas to Lake Okeechobee. As a result of development around Lake Okeechobee and the estuaries that are connected to Lake Okeechobee, estuarine conditions have also been adversely impacted, resulting in salinity and nutrient fluctuations. The measurement of water turbidity in lacustrine and estuarine ecosystems allows researchers to understand important factors such as light limitation and the potential release of nutrients from re-suspended sediments. Based on a strong correlation between water turbidity and normalized water-leaving radiance at the near-infrared (NIR) band ($nL_w(869)$), a new satellite water turbidity algorithm has been developed for Lake Okeechobee. This study has shown important applications with satellite-measured $nL_w(869)$ data for water quality monitoring and measurements for turbid inland lakes. MODIS-Aqua-measured water property data are derived using the shortwave infrared (SWIR)-based atmospheric correction algorithm in order to remotely obtain synoptic turbidity data in Lake Okeechobee and normalized water-leaving radiance using the red band ($nL_w(645)$) in the Caloosahatchee and St. Lucie estuaries. We found varied, but distinct seasonal, spatial, and event driven turbidity trends in Lake Okeechobee and the Caloosahatchee and St. Lucie estuary regions. Wind waves and hurricanes have the largest influence on turbidity trends in Lake Okeechobee, while tides, currents, wind waves, and hurricanes influence the Caloosahatchee and St. Lucie estuarine areas.

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* *Corresponding author*. Tel.: +1 301 683 3325.
E-mail address: Menghua.Wang@noaa.gov (M. Wang).
[1] Present address: US Army Corps of Engineers, Pittsburgh, PA, USA.
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1. Introduction

The collective ecosystems of southern Florida are valued for their ecosystem services, aesthetic beauty, abundance of recreational activities and contributions to local economies. Lake Okeechobee provides residents and visitors with a source of drinking water, a sport fishing industry, and irrigation water for surrounding agricultural areas. The adjacent Caloosahatchee and St. Lucie estuaries are also well known for the abundance of ecosystem services and recreational opportunities they provide, in addition to the functional role they serve as drainage basins for Lake Okeechobee overflow (Fig. 1). While these ecosystems have provided numerous benefits to human societies, they have also been modified to suit many human needs, such as flood control, irrigation and navigation, etc. In addition, developmental modifications have taken a toll on the organisms occupying these disturbed habitats and natural resource managers are using science to identify harmful trends in order to restore these valued resources, which have been documented since 2005 on a yearly basis in South Florida Environmental Reports (http://www.sfwmd.gov/sfer/).

Located in southern Florida, Lake Okeechobee is the second largest freshwater lake (~1730 km^2) located entirely within the contiguous United States (Fig. 1). Although Lake Okeechobee is large in areal extent, it is relatively shallow with a mean depth of ~2.7 m. The lake can be classified into three regions based on primary producers (Havens, 2003). The littoral zone (water depth ≤~1 m) is located primarily along the shoreline of the western half of the lake and consists of a suite of biologically diverse plant species, which provide excellent habitat for the spawning of fish. The near shore zone (water depth ~1–2 m), also located along the western half of Lake Okeechobee's coast, is comprised of submerged aquatic vegetation (SAV) and wave tolerant emergent plants and contains a substrate of both sand and peat. The pelagic zone (water depth of ~2.5–5 m) is largely devoid of vegetation and has a muddy substrate (James et al., 2008). The climate and rainfall in the area is characteristic of subtropical locations with a dry (November–April) and wet (May–October) season. However, tropical storms and climatic events, such as hurricanes and El Niño/La Niña oscillations, can substantially alter the hydrology and hydrodynamics of the lake.

In response to devastating hurricanes in the early half of the 20th century, the state of Florida and the Army Corps of Engineers enclosed Lake Okeechobee with the Herbert Hoover dike in order to contain hurricane related flooding. The Herbert Hoover dike also stores freshwater from the watershed in Lake Okeechobee during the dry season for municipal and agricultural water supplies. Drainage canals built to divert excess water from Lake Okeechobee during the wet season now drain most excess water through the Caloosahatchee River to the Gulf of Mexico (west) and the St. Lucie Canal to the Atlantic Ocean (east) instead of the historical drainage route through the Everglades (south) (Fig. 1). While some excess water is routed through southern flowing irrigation canals, these canals divert smaller amounts of water to agricultural areas and the Everglades adjacent to Lake Okeechobee when compared to the Caloosahatchee River and St. Lucie Canal, which discharge water into their estuaries (James et al., 2008).

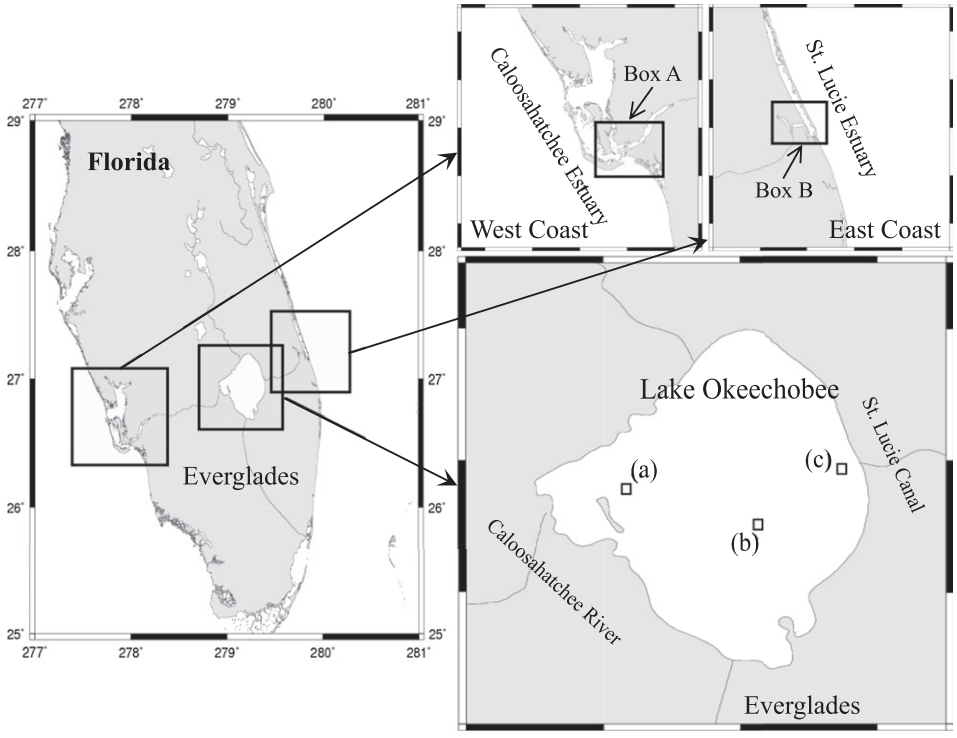

Fig. 1 – Maps of Lake Okeechobee and the Caloosahatchee and St. Lucie estuaries. The study area is marked with three specific locations in Lake Okeechobee (a–c) and Boxes A and B in the Caloosahatchee and St. Lucie estuaries for quantitative studies.