ESTIMATING TURBIDITY NEAR A DREDGE OPERATION USING A WEATHER BALLOON-MOUNTED CAMERA

by

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ABSTRACT

To date, remote sensing information acquired from satellites and aircraft (manned planes; unmanned aerial systems [UAS]) has been used to estimate suspended sediment concentrations on a large spatial scale. Remotely sensed data can be used to create a georeferenced snapshot (e.g., orthomosaic) of the sediment plume which can be integrated into a digital map to measure the scale of the plume, providing insights into other useful information such as the exposure of nearby resources to the plume, plume patterns, and areas of deposition. Additionally, empirical relationships between suspended solids concentration (SSC in mg/L), turbidity (nephelometric turbidity units [NTU]) and spectral wavelengths in the visible (400-700 nm) and near infrared (700-900 nm [NIR]) have been established. Predicting and monitoring the spatial and temporal extent of suspended sediment plumes produced from the excavation, transport, and placement of dredged material are important management practices to avoid unacceptable ecological impacts associated with operations and often necessary to comply with regulatory requirements. Satellite technologies can be too coarse spatially and temporally, making them an impractical option to use for determining short-term impacts, such as a dredge plume on a specific area. Manned aircraft can provide higher spatial and temporal resolution imagery, but expensive image acquisition and operating costs make repeated flights impractical. The improvement of UAS platform technologies allows for the opportunity to collect imagery with high spatial and temporal resolution, but the Federal Aviation Administration (FAA) and U.S. Army rules governing UAS operations can hinder their use near dredging operations. Similar remote sensing techniques using tethered airships may be more reliable and operations repeatable in most project settings because they are less restricted by FAA and U.S. Army regulations. This option can produce desirable high spatial and temporal resolution of the optical water properties over a long monitoring period (e.g. hours to days of air time). This advantage can be important when considering the temporal variability of SSC near a coastal dredging operation can be magnified by tides, prevailing winds and currents, and river flow which can result in a continuous movement of water. In situ grab samples can be concurrently collected with spectral reflectance data to build an empirical relationship but this is often not adequate if too few samples are collected for waters in motion. More ideal would be an automated turbidity monitoring station synched with image collection resulting in hundreds of samples. Because the airship is tethered it is limited to a smaller area (e.g., 2-8 acres depending on altitude and sensor), but this option could be well suited for turbidity monitoring near ecological sensitive areas that may benefit from continuous measurements during dredging operations (e.g., oyster reef, seagrass). Additionally, the tethered airship provides an opportunity to collect data over longer periods of time which can provide insight into useful information about the temporal variability of spectral reflectance correlated to SSC or NTUs in moving water.

The objective of this research was to estimate the concentration of suspended sediments within an active dredge plume using reflectance in the visible spectrum collected remotely using a relatively low-cost platform. To achieve this overall objective, a low-cost monitoring system was developed consisting of a weather balloon-mounted consumer grade digital camera to acquire turbidity reflectance in the visible bands (400-700 nm) of a shallow coastal area affected by a pipeline discharge of dredged material. The study area was located on the Gulf of Mexico shoreline (29°43'48.04"N, 93°0'46.48"W) immediately west of a rock jetty extending from the mouth of the Mermentau River, south of Grand Chenier, LA, USA. This area is part of the Chenier coastal plain which is characterized by low gradient muddy shorelines or mud flats with an abundance of sediments deposited form tides and rivers. The balloon was tethered and launched approximately 30 m from the shoreline over water depths that

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ranged 1-2 m. A cutterhead pipeline dredge, *Ingenuity*, excavated material from the mouth of the river near the end of the west rock jetty. Dredged material was discharged into the shallow coastal waters of the Gulf of Mexico via a pipeline positioned on top of, and perpendicular to, the west rock jetty. The combination of primarily south, southeast winds, and the jetty, resulted in water currents that moved southeast into the corner where the jetty and shoreline met and then continued west along the shoreline. Observations confirmed that a portion of the sediment plume migrated along this path and extended down the shoreline for serval miles. The study area was subjected to primarily dredge plume inputs and also naturally deposited sediment inputs from Mermentau River along with low wave energy and tidal influences. To enhance the spectral reflectance sensitivity, a white reference surface target and white reference submerged target (suspended 7.62 cm below the water surface) were situated to be visible in each image. A turbidity sensor was mounted on the submerged reference target and another sensor was located immediately to the side of the white reference surface target to represent an open water area. The sensors were submerged 7.62 cm below the water surface and turbidity was concurrently measured with image acquisition. For image data post-processing a computer script was developed to digitize regions of interest (ROI) in order to select pixels from the white reference surface target, white reference submerged target, and the open water area. For each ROI, the mean RGB spectral reflectance data was extracted. A relative reflective index was created by dividing the white reference submerged target reflectance or the open water area reflectance by the white reference surface target reflectance. A regression was used to explore the relationship between the relative reflective index and turbidity for the submerged target and the open water area.

Images were successfully acquired concurrently with turbidity measurements. The mean turbidity was 25 NTU and ranged from 11 to 114 NTU. These turbidity levels are within a range commonly experienced near a dredging operation. The total RGB intensity was greatest for the white surface target, followed by the white submerged target, and open water (Fig 1). The open water RGB intensity remained relatively constant throughout the sampling period with only a small decrease over time which suggests the sensor was likely saturated by environmental conditions in the open water area whereas the white surface and submerged target increased the available reflectance. The relative open water reflectance calibration (open water reflectance/white reference surface target reflectance) showed no relationship between relative reflectance and turbidity, therefore, under these field conditions it would be difficult to rely on visible reflectance data acquired from the open water as an indicator of turbidity (Fig 2). The importance of a white reference surface target and submerged target calibration is demonstrated by the relative submerged reflectance (white reference submerged target reflectance/white reference surface target reflectance) plotted against the turbidity which resulted in an inverse logarithmic trend and r^2=0.7953. A logarithmic relationship is expected because increasing turbidity would decrease spectral sensitivity of the visible bands measured at the submerged target. The use of surface and submerged white reference targets increased spectral reflectance sensitivity and when correlated to concurrently measured turbidity reduced the uncertainty of monitoring and predicting turbidity in a turbid shallow water coastal environment.

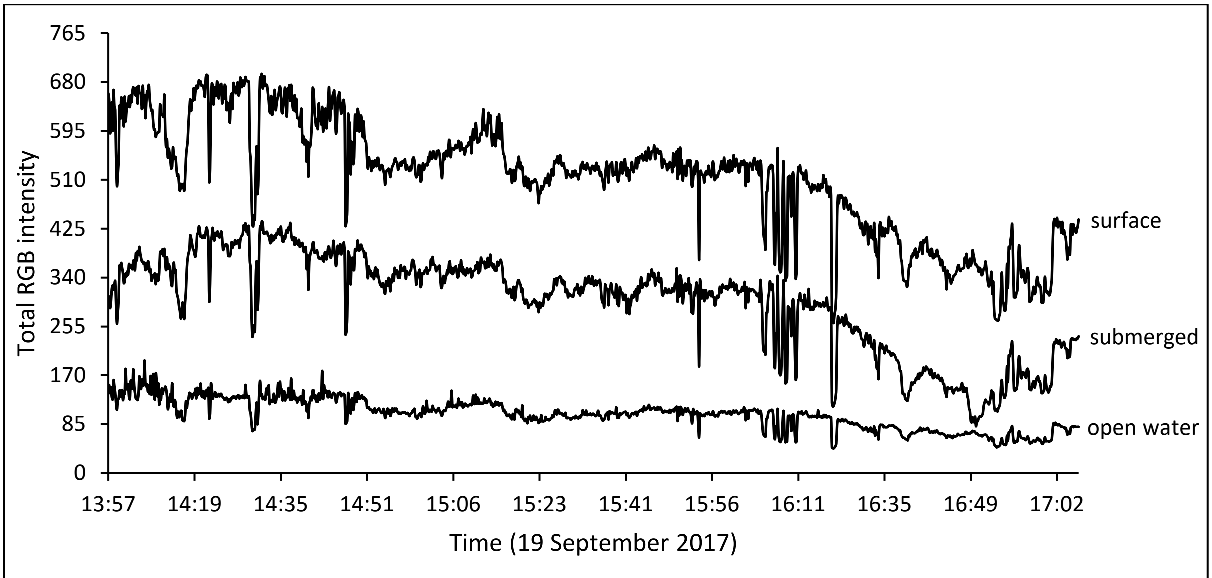

Figure 1. Total RGB intensity measured for the white surface reference target (surface), the submerged target, and the open water area adjacent to the surface target.

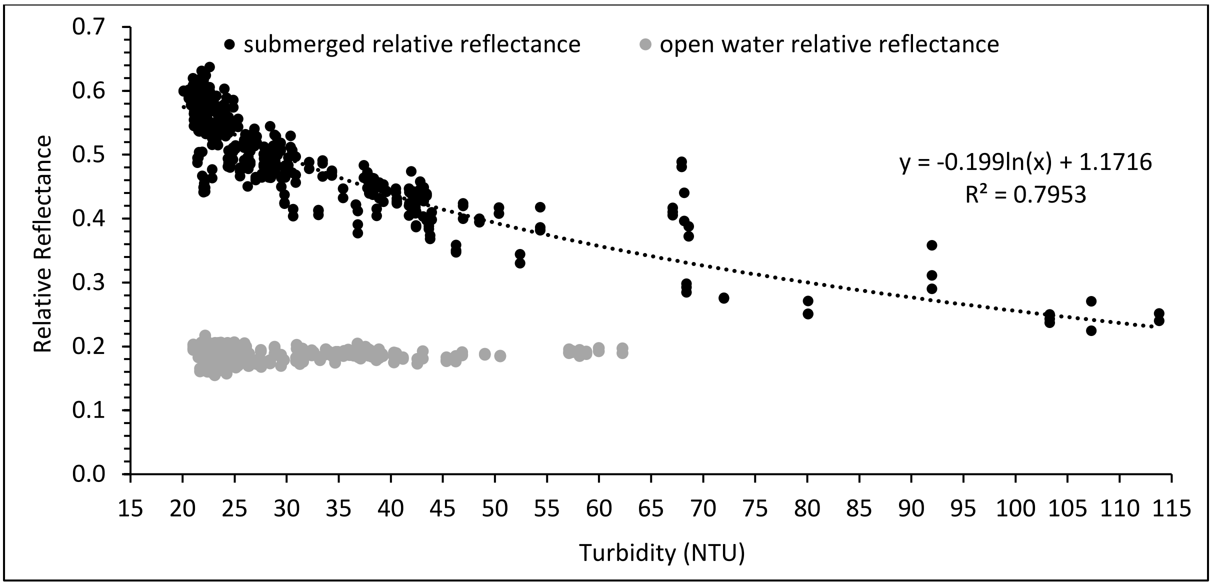

Figure 2. Scatter plot of relative submerged reflectance (white reference submerged target reflectance/white reference surface target reflectance) and open water reflectance (open water reflectance/white reference surface target reflectance) and corresponding turbidity.