Estuarine, Coastal and Shelf Science 149 (2014) 68–79

Contents lists available at ScienceDirect

Estuarine, Coastal and Shelf Science

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

Mapping and assessing seagrass bed changes in Central Florida's west coast using multitemporal Landsat TM imagery

Ruiliang Pu [a,*], Susan Bell [b], Cynthia Meyer [a]

[a] School of Geosciences, University of South Florida, Tampa, FL 33620-5200, USA
[b] Department of Integrative Biology, University of South Florida, Tampa, FL, USA

A R T I C L E I N F O

Article history:
Received 2 February 2014
Accepted 20 July 2014
Available online 1 August 2014

Keywords:
seagrass change
submerged aquatic vegetation (SAV)
image preprocessing
remote sensing
Landsat TM imagery
hurricane
Florida

A B S T R A C T

Some seagrass meadows in coastal shallow waters have displayed large scale changes in seagrass spatial extent and hurricanes and/or tropical storms have been suggested as factors responsible for reduction in coverage. Taking advantage of the incidence of three tropical storms passing near a study site along the central west Florida coast within a two-month period in 2004, we evaluated whether satellite remote sensing techniques (Landsat 5 Thematic Mapper (TM) imagery) are useful for assessing dynamics of seagrass (=submerged aquatic vegetation: SAV) cover/abundance in response to these multiple disturbances. We also examined whether an image preprocessing procedure, which included water column correction, applied to the Landsat TM images could further improve the classification and mapping of detailed SAV coverage. We compared a historical set of Landsat TM images, acquired in Fall 2003 and Fall and late Summer 2005, which were processed to classify %SAV cover into five classes using a maximum likelihood classifier. Importantly, our experimental results demonstrated that the application of the image preprocessing procedures led to an overall accuracy 2–14% improvement in SAV classification due to water column correction compared to that currently reported in the literature when similar Landsat TM data are utilized. Based upon the classification results mapped from the TM images and as well as a similar classification of SAV interpreted from aerial photographs collected before and after the passage of these same storms, SAV coverage over the study areas was found to increase about 6% (integrating SAV losses and gains) by 2005/2006 in comparison to cover levels present prior to the repeated storm activity. We conclude that heavy rains during 2004 along with physical disturbance from gale force winds from the tropical storms/hurricanes did not produce any SAV bed loss at the study site that was sustained for more than one year after multiple storm passage.

1. Introduction

Globally, the spatial extent of seagrass meadows has been reported to display both small and large scale changes (Robbins and Bell, 1994; Knudby et al., 2010; Lyons et al., 2013). Factors underlying loss of extensive seagrass coverage are not well known but both natural drivers and anthropogenic effects (e.g., land-based pollution, erosion and nutrient over enrichment) have been implicated (e.g., Dekker et al., 2005; Gullström et al., 2006; Shapiro and Rohmann, 2006; Howari et al., 2009; Yang and Yang, 2009; Barillé et al., 2010; Lyons et al., 2013). Understanding the exact triggers of seagrass gain or loss remains a challenging task.

Among natural events, extreme weather events such as tropical storms and hurricanes have garnered attention as likely candidates underlying loss of seagrass (e.g., Byron and Heck, 2006). In selected cases, reduced seagrass cover in near shore marine communities has been noted after the occurrence of hurricanes/tropical storms, and extent of loss is often linked to the hurricane strength and duration. Both direct and indirect physical impacts (e.g., obliterating seagrass beds and lowering salinity and optical water quality) have been advanced to explain declining seagrass cover (Yang and Huang, 2011; Carlson Jr. et al., 2010; Steward et al., 2006). Direct physical impacts, often associated with moving sediments, can create blowouts within seagrass beds or bury aboveground shoots. Additionally, edges of seagrass beds may be eroded, and/or seagrass biomass detached from rhizomes from hydrodynamic forces. Hurricane-associated impacts on water column characteristics, including increased turbidity or periods of reduced salinities (Campbell and McKenzie, 2004; Ridler et al., 2006), have also been

* Corresponding author.
E-mail address: rpu@usf.edu (R. Pu).

http://dx.doi.org/10.1016/j.ecss.2014.07.014
0272-7714/

suggested as environmental drivers of seagrass decline (see Carlson Jr. et al., 2010). To date, however, the impacts of tropical storms/hurricanes have been reported to have both deleterious or no effects on seagrass cover.

To understand the role of large scale natural disturbances, such as extreme weather events, on seagrass distribution and abundance, it remains critical that data be available to document spatiotemporal changes (growth and decline) of seagrass beds. However data on seagrass distribution and abundance both before and after declining cover may not always exist (see Rasheed et al., 2014). Assessment methods including collection of periodic field observations or historical review of aerial photography are commonly utilized to provide baseline data but these may be spatially limited (see Carlson Jr. et al., 2010). Of concern is that availability of adequate information of spatial extent of seagrass cover, both before and after tropical storms/hurricanes, limits detection of seagrass loss or gain.

During 2004, three major hurricanes: Charley, Frances, and Jeanne passed over the central west coast of Florida, USA (Fig. 1) and we selected a site along the central west Florida coast line to evaluate whether seagrass cover displayed spatially extensive loss of seagrass after passage of these storms. While other studies have evaluated response of seagrass to a single storm event, rarely has a response to the passage of multiple storms within the same season been investigated. The site subjected to impacts of multiple storms has also served as the study site for assessing seagrass resources using both Landsat TM and EO-1 ALI/Hyperion as satellite remote sensing sensors (Pu et al., 2012; Pu and Bell, 2013). Building upon these studies, we sought to investigate whether large scale changes (exceeding 30 m × 30 m) in seagrass coverage followed the combined impacts of three tropical storms. Specifically, we investigated the potential of moderate resolution satellite remote sensing, such as Landsat series products, for use in the development of detailed maps of seagrass resources and assessment of seagrass distributional change.

Satellite remote sensing has been used over the last three decades to map and monitor changes of seagrass habitats in shallow coastal waters (e.g., Ackleson and Klemas, 1987; Mumby et al., 1997; Schweizer et al., 2005; Gullström et al., 2006; Howari et al., 2009; Barillé et al., 2010; Pu and Bell, 2013; Lyons et al., 2013). However, most current methods and techniques, while providing an opportunity to map seagrass distribution over large areas relatively rapidly, also face some limitations. Specifically, current methods and techniques utilizing the moderate resolution satellite remote sensing data (e.g., Landsat TM) directly use either raw data (i.e., in digital number: DN) or simply radiometrically corrected to at-

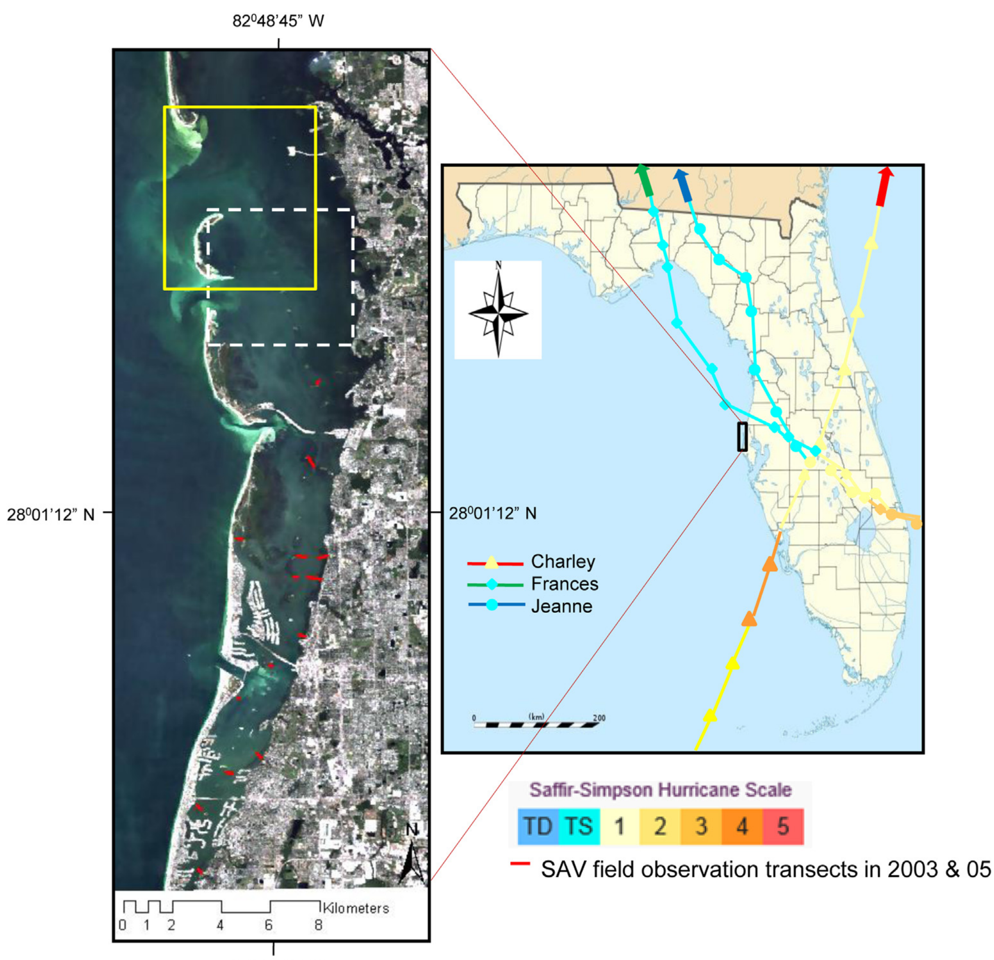

Fig. 1. Location of the study areas, St Joseph Sound and Clearwater Harbor, Pinellas County, Florida, USA. The blown true color composite image shows locations of permanent survey transects in 2003 and 2005, indicated by "–" symbol in red. Paths of three major hurricanes (right map): (1) Hurricane Charley, August 13, 2004; (2) Hurricane Frances, September 6, 2004; and (3) Hurricane Jeanne, September 26, 2004. The white dashed box in the left image shows the location of color composite images in Fig. 2. The yellow box in the left image is the location of color composite images in Fig. 5. The Saffir-Simpson Hurricane Scale was used to depict the three hurricanes' intensity changes along their tracks (SSHWS, 2014). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)